COMPLEX SCHEDULES OF REINFORCEMENT: RESPONSE-REINFORCER TEMPORAL RELATIONSHIPS, THE ROLE OF BRIEF STIMULI, AND UNIT SCHEDULE PERFORMANCE AS AN OPERANT IN PIGEONS

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COMPLEX SCHEDULES OF REINFORCEMENT: RESPONSE-REINFORCER TEMPORAL RELATIONSHIPS, THE ROLE OF BRIEF STIMULI, AND UNIT SCHEDULE PERFORMANCE AS AN OPERANT IN PIGEONS

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SUMMARY

Three experiments investigated the variables assumed to control performance under second-order and conjunctive schedules of reinforcement. Pigeons served as subjects. In Experiment I, the effects on performance of arranging responses and reinforcers in different temporal relationships were compared by adding a fixed-ratio response requirement to a fixed-interval schedule either as a conjunctive schedule or as a unit schedule in a second-order schedule. Overall rates of responding increased over the fixed-interval rate. Responding was maintained under both schedules throughout the ranges of values examined (1 - 300 responses). The second-order schedule maintained higher terminal rates of responding, while the conjunctive schedule controlled shorter pause times. Consequent stimuli and its association with food were studied in Experiment II under both the conjunctive and the second-order schedules. Overall rates of responding were not further increased. Evidence was presented in Experiment II that the brief stimuli in second-order schedules may be serving a discriminative function, resulting in within-unit patterning. In Experiment III, additional unit schedules were added as a conjunctive requirement to the second-order schedule. The second-order schedule performance was subsequently altered in a similar manner as when addition-

al single responses are required under a fixed-interval schedule of reinforcement. Finally, from all three experiments, the regenerative property of the fixed-interval schedule was seen, whether a single response or a complex unit was in question.

CHAPTER I

INTRODUCTION

Identifying those events which can strengthen and maintain behavior is an important step in the experimental analysis of behavior. One such event is a reinforcer. A critical feature of a reinforcer is that its presentation following some response increases the future probability of the occurrence of that class of responses. However, a reinforcer need not follow each response in order to maintain behavior; it need only follow a response intermittently. A reinforcement schedule specifies the conditions which must be met in order for a reinforcer to occur. Two relatively simple arrangements are represented by fixed-interval and fixed-ratio schedules. A fixed-interval schedule (FI t) specifies that the first response after a fixed period of time (t) will be followed by a reinforcer. A fixed-ratio schedule (FR n) specifies that reinforcement depends upon the execution of a fixed number of responses (n).

Schedule requirements for reinforcement interact with ongoing behavior to produce both stereotypic and dynamic effects (Zeiler, 1976). A stereotypic effect of a schedule is demonstrated by the consistency in characteristic rates, as well as the temporal distribution, or pattern, of responses that occur between successive presentations of the reinforcer. For example, fixed-interval schedule performance is characterized by a pause after reinforcement followed by an increased rate of responding until the next reinforcer. The uniformity of the behavior under particular

schedules among individuals of the same species, across species, and within the same individual over time demonstrates the generality of laws governing schedule-controlled behavior. The performance generated by these schedules of reinforcement is repeated in the same form in the future; this consistency in patterns of behavior is a defining attribute of reinforcement (Zeiler, 1976).

Dynamic effects of schedules result from interaction between ongoing behavior and schedule requirements that can lead to changed performance. To illustrate, under a fixed-interval schedule, only a single response is required after the interval has elapsed for a reinforcer to occur, thus the number of responses emitted during the interval is free to vary. The emission of a small number of responses during successive intervals may have a "feedback" effect which can strengthen subsequent responding since the probability of reinforcement per response (I.E., responses per reinforcement) is high. The increased number of responses occurring in succeeding intervals results in a reduction in probability of reinforcement per response (i.e., more responses per reinforcement), ultimately leading to a reduction in the number of responses per interval, and so on (Dews, 1970). It should be noted that dynamic effects may be seen only when certain variables, in this case the number of responses, are free to vary.

Schedule requirements also impose <u>direct</u> and <u>indirect</u> effects. A fixed-interval schedule directly specifies the minimum interreinforcer time, while the number of responses are left free to vary. On the other hand, a fixed-ratio schedule directly specifies the number of responses which must be completed, but the interreinforcer time may vary, depending upon the rate of execution of responses by the organism. However, the

number of responses per reinforcement in the fixed-interval schedule and the interreinforcer time in the fixed-ratio schedule may have indirect effects upon performance. Zeiler (1976) suggests that since some schedules impose directly what other schedules simply make possible, schedule effects may be analyzed in the following manner: the variables which are hypothesized to be affecting behavior indirectly under one schedule can be imposed directly upon another schedule, and the resulting performance compared to the original schedule performance. For example, to assess the role of variation in number of responses per reinforcement in determining interval performance, Herrnstein and Morse (1958) added a fixed-ratio requirement to a fixed-interval schedule, I.E., a conjunctive FI t FR n schedule. Under the conjuctive schedule, both requirements must be satisfied in order for the reinforcer to occur. Under a conjunctive FI t FR n schedule, at least nl responses must be emitted during the interval in order for the first response after the interval (t) has elapsed to be reinforced. Hernnstein and Morse found that requiring as few as 10 responses (n=10) under an FI 15-minute schedule, altered the pattern of responding, and decreased overall response rates, even though the average number of responses emitted per interval under control conditions was about 300. Thus, by directly imposing a response requirement larger than that of a simple interval schedule, both rates of responding and the characteristic distribution of responses over time, the pattern, was changed. This indicates that the single response requirement under a fixed-interval schedule is important in maintaining the schedule-characteristic rates and stereotypic patterns of responding.

Another type of complex schedule, a second-order schedule, also

may impose directly a fixed number of responses that must be emitted before a reinforcer is delivered under an interval schedule. A second-order schedule which specifies that the first fixed-ratio of size n completed after an interval (t) has elapsed will be reinforced can be denoted so FI t (FR n). When a ratio requirement is added to an interval schedule in a second-order schedule arrangement, the fixed-interval pattern is maintained (Bradford & Marr, 1976; Kelleher, 1966A; Shull, Guilkey and Witty, 1972) and the overall response rate enhanced when compared to a simple fixed-interval (Bradford & Marr, 1976). A problem arised when an attempt is made to compare conjunctive and second-order schedules. Behavior maintained under any schedule of reinforcement, is multiply-determined (Ferster Skinner, 1957; Morse, 1966A; Zeiler, 1976). In order to understand why these two schedules maintain different patterns and rates of responding, each variable that is hypothesized to be controlling the behavior must be studied directly. A careful examination of these two schedules reveal several distinctions which may account for the differences in performance. First is the <u>temporal relationship</u> between the response requirement and the reinforcer. Under the second-order schedule, the ratio requirement must be completed after the interval has elapsed; under the conjunctive schedule, the ratio requirement may be met at any point during the interval. Second, there is the role of consequent stimuli (i.e. stimuli which are response-produced) found in the second-order schedule, but not the conjunctive schedule. Finally, there is the question of the nature of the functional operant in the second-order schedule, i.e., what is the appropriate unit of analysis. In directly studying the variables which control behavior in complex schedules, we are able to determine if the

principles which govern behavior under simple schedules of reinforcement extend to more complex schedules.

The following experiments were designed to investigate the variables which may be controlling performance under second-order and conjuctive schedules of reinforcement. Experiment I compared the effects of arranging responses and reinforcement in different temporal relationships. Experiment II introduced consequent stimuli which could alter responding by either increasing or decreasing rates and/or by changing the pattern of responding. This experiment also examined the role of a consequent stimulus by manipulating its association with food. Finally, Experiment II and Experiment III tested for the cohesive properties of unit performance under the second-order schedule. Experiment III determined if adding additional unit-schedule requirements to a second-order schedule altered performance in the same manner as when additional single responses are required under a fixed-interval schedule of reinforcement.

The specific goals of the experiments were:

1. To investigate the effects upon performance of different temporal relationships between response requirements and reinforcers.
2. To investigate the effects of response-produced brief-stimulus presentations upon complex schedule performance, and determine the extent to which these effects depend upon the association of the stimulus with food.
3. To test the extent to which unit-schedule performance is executed as a single response.
4. To attempt to extend the basic principles controlling rates and patterns of responding under simple schedules of reinforcement to more complex schedules.

CHAPTER II

EXPERIMENT I: RESPONSE-REINFORCER TEMPORAL CONTIGUITY

Introduction

Temporal Contiguity and the Law of Effect.

The Law of Effect states that when a response is followed by a reinforcer it more likely to reoccur. Zeiler (1976) emphasized temporal contiguity as the controlling variable in the response-reinforcer dependency, i.e., that the reinforcer strengthens and maintains the response which immediately precedes it. The assumption of close temporal contiguity between a response and a reinforcer in the Law of Effect has been questioned recently (Baum, 1973; Bloomfield, 1972) based on empirical findings that responding can be maintained when there is only a correlation between a response and the reinforcer (see also Rescorla, 1967: Rescorla and Lolordo, 1965). Baum suggests that the Law of Effect as presently stated relating a response and a reinforcer as discrete events in time is too limiting and does not explain certain results, and, as such, should be replaced with a "Correlational" Law of Effect. He further suggests that greater flexibility is achieved if the relationships are stated in more molar terms: "Behavior increases in frequency if the increase is correlated with an increase in rate of reinforcement or decrease in rate of aversive stimulation" (1973, p. 145). For instance, Herrnstein and Hineline (1966) found that avoidance responding in rats can be maintained if responding reduces the frequency of shock. There was a correlation be-

tween responding and a decrease in the number of shocks, but not a one-to one relationship.

Response-reinforcer dependency and temporal contiguity are difficult to separate since the behavior upon which the reinforcer is dependent is usually confounded with the behavior that is temporally contiguous with the reinforcer. Hawkes and Shimp (1975) attempted to reinforce a pattern of responses rather than a single keypeck in pigeons. In this experiment the keypeck that produced the reinforcer was but a small percentage of the required behavior. Hawkes and Shimp made reinforcement dependent upon a particular temporal distribution of responses with a progressive increase or decrease in rate within a 5-second trial and found that responding was maintained. Furthermore, the performance engendered by the increasing-response-rate requirement closely resembled the pattern found under a fixed-interval schedule. Thus, their results support Baum's contention of a more "molar" law of effect.

Using pigeons as subjects, Catania (1971) analyzed the role of responses which precede the reinforcer-producing response. In another way, Catania "tagged" preceding responses by moving them to a different location (i.e., another key). For instance, under a variable-interval schedule, a response on key A produced a reinforcer after a variable period of time, with the added stimpulation that the response on key A had to be preceded by a response on a different key, key B. Separating the responses in this manner had no consistent effect on the total number of responses emitted, but it did affect the way in which responding was distributed between the two keys. When averaged across all the subjects, key B maintained about as many responses as did key A. Thus, the rein-

forcer acted upon all the earlier responses, not simply the one that produced it. As catania pointed out "...When we reinforce the last response in a sequence of responding we strengthen all the responses in the sequence" (.971, p.286).

Staddon and Frank (1975) in a test of Baum's hypothesis concerning the correlational relationship between a reinforcer and a response, arranged three different types of response-reinforcer dependencies and temporal relationships, and manipulated the interreinforcer interval value. Performance of pigeions under three schedules were studied: (1) A fixed-time schedule (FT t) wherein the reinforcer is delivered independently of responding at the interval (t); (2) A conjunctive FT t FR 1 schedule; and (3) A recycling conjunctive FT t FR 1 schedule. Under the conjunctive FT t FR 1 schedule, a reinforcer was delivered at the end of the interval (t) if and only if at least one response had been emitted during the interval. The conjunctive schedule was used to alternate response-reinforcer contiguity, but when the bird paused beyond the interval, the first response produced food. In order to eliminate the occasional response-reinforcer contiguity found in this schedule, a recycling conjunctive schedule was used. If the response had not been emitted by the time the interval cycle was completed, the interval recycled, and the reinforcer could be delivered only at the end of a subsequent cycle. The schedule continued to recycle until a response was emitted. Staddon and Frank pointed out that of the two variables under investigation, interreinforcer interval had the great-effect on both response rates and patterns, with the type of dependency having a lesser effect. At longer interreinforcer intervals, responding usually assumed a bitonic pattern, with a pause after reinforcement followed

by increased responding after which responding decreased until the next reinforcer delivery. The conjunctive schedule maintained higher response rates than the other two schedules, presumably because of the occasional contiguity afforded by that schedule i.e., if the bird paused beyound the interval, the first response produced food, reinstating the response-reinforcer temporal contiguity. Staddon and Frank reasoned that if the controlling variable were a molar relationship, i.e., that a response was correlated with a reinforcer, then the recyling conjunctive schedule should have been able to sustain responding. In fact, the recycling schedule was relatively ineffective without the faciliating effects of a very short interreinforcer interval; at longer intervals, responding was not maintained and only a small percentage of the reinforcers were delivered.

Thus, the empirical findings have not clearly established the controlling variables in the response-reinforcer dependency. One way to assess the role of temporal contiguity and its effect on performance is to arrange reinforcement schedules that have the same response requirements per se, but differ only in the temporal relationship of the response requirement and the reinforcer. For example, Shull (1970) compared a fixed-interval schedule (FI t) with a conjunctive FT t FR 1 schedule. The two schedules were identical in their response requirements, i.e., one response was necessary in order for the reinforcer to occur. However, the fixed-interval schedule assured a close temporal relationship between the response requirement and the reinforcer, since the first response emitted after the interval had elapsed was reinforced. Under the conjunctive schedule, FT t FR 1, the reinforcer was delivered at the end of the interval (t) if and

only if a response had been emitted at any point during the interval. Shull found that regardless of the response-reinforcer temporal relationship, the time taken to begin responding seemed to be controlled by the periodicity of the reinforcer. On the other hand, response rate was affected by how the reinforcer was arranged. Under the conjunctive schedule, response rates were reduced, especially rates at the end of the interval. Thus, the temporal relationship of the response to the reinforcer affected one aspect of the schedule, rate, but not the pause component of the stereotypic pattern.

Temporal Relationships of Response Requirements and Reinforcers

Herrnstein and Morse (1958) and Barrett (1975) found that adding a ratio requirement to an interval schedule to form a conjunctive schedule (i.e.,CONJ FI t FR n, where n is greater than one), produced consistent effects upon performance. Compared to an interval schedule of the same parameter value, the conjunctive schedule engendered lower overall response rates, especially in the terminal segments of the interval. Although a wide range of parameter values for both the interval and ratio was studied, the pattern of responding from both these experiments was consistent. The performance engendered by the conjunctive shcedule consisted of a pause after reinforcement followed by a high rate of responding, approximating the size of the ratio requirement, and than a decrease in the response rate until the next reinforcer presentation. Thus, the temporal distribtuion of responses was bitonic.

Another type of complex schedule, the second-order schedule, can also require more than one response to be emitted under an interval sche-

dule, but, while tending to increase response rate, does not alter a fixed-interval pattern. Under a second-order schedule. The behavior engendered by one schedule, designated the unit schedule, is treated as a unitary response which is, in turn, reinforced under a second schedule (the second-order schedule, SO). For instance, a second-order schedule which as the same response requirement as the conjunctive schedule FI t FR n treats the behavior produced by a fixed-ratio requirement as a unitary response that is then reinforced under a fixed-interval schedule. Thus, the first fixed ratio of size N executed after the fixed interval has elapsed is reinforced with food. This schedule is designated SO FI t(FR n). A second-order schedule FI t(FR n) and a conj FI t FR n have the same response requirement (more than one response is required,) but a close temporal relationship between the fixed-ratio performance and the reinforcer is explicitly arranged under the second-order schedule while this is free to vary under the conjunctive schedule. The ratio performance and the reinforcer come in close contact under the conjunctive schedule only when the organism pauses throughout the interval.

In summary, a conjunctive FI t FR n schedule engenders a bitonic pattern: there is a pause after reinforcement, an increased rate of responding, and then a decrease in response rate until the next reinforcer presentation (Barrett, 1975). The overall rates of responding are decreased when compared to a fixed-interval of the same parameter value (Barrett, 1975; Herrnstein & Morse, 1958). Contrary to these findings, when a fixed-ratio response requirement is added to an interval schedule under a second-order schedule, SO FI t(FR n), the monotonically increasing response rate during the interval is not disrupted (Kelleher, 1966A; Shull

et al., 1972). Furthermore, overall response rates may even increase when compared to a fixed-interval schedule (Bradford & Marr, 1976).

One aspect of the second-order schedule that may be controlling the differences in patterns and response rates between conjunctive and second-order schedules may be the temporal contiguity of the response requirement and the reinforcer. Under the second-order schedule, the fixed-ratio requirement must be completed after the interval has elapsed thus assuring that the ratio will be emitted in close temporal proximity to the reinforcer. Under the conjunctive schedule, the ratio requirement may be completed at any point during the interval. The only time when the ratio performance and the reinforcer come in close temporal contact is when the organism pauses the entire length of the interval, so that the ratio requirement must be satisfied after the interval has elapsed.

Goals.

The first experiment compared second-order and conjunctive schedules of reinforcement in which the response requirements per se were indentical (i.e. the same ratio requirement) but the temporal relationship of the required responses and the reinforcer was different. Under the second-order schedule FI t(FR n) the first ratio requirement completed after the interval had elapsed was reinforced, assuring a close temporal relationship to the reinforcer. Under the conjunctive FI t FR n schedule, the ratio requirement could be satisfied at any point during or after the interval.

The following hypothesis was examined:

H1: The rates and patterns of responding engendered under a conjunctive FI t FR n schedule will not differ from the same performance measures under a second-order FI t(FR n) schedule as a result of different

response-reinforcer temporal relationships.

Method

Subjects

The subjects for experiment I were three experimentally naive white carneaux pigeons obtained from the palmetto pigeon plant, Sumter, S. C. and maintained at 80% of their free feeding weight.

Apparatus.

The experimental chamber for experiment I was a Grayson-Stadler 3-key unit (Ferster & Skinner, 1957) in which the two side keys were covered. The center response key, 2.0 cm in diameter, could be operated with a minimum force of 0.18 N and could be transilluminated from the rear by either a red, blue or amber #1829 28VDC almp. The food magazine aperture was 5.1 cm x 4.4 cm located 13.5 below the center key and was illuminated by a white GE1OC7D 120VAC lamp during the feeder cycle. In addition, a white GE 10C7D 120VAC light was mounted behind a translucent screen on the key panel and provided general illumination during the cycle. White noise in the experimental chamber masked extraneous noises. Standard relay programming equipment in a seperate room operated all clocks, counters, timers and a print-out counter. A cumulative recorder provided a permanent graphical record of the rates and patterns of responding.

Procedure.

The birds were first trained to eat from the food hopper and then trained to peck the trans-illuminated key. Each peck produced 3-seconds access to mixed grain. The schedule was then changed to a fixed-interval whose length was gradually increased until responding was maintained under

a FI 20-minute schedule with 10-seconds access to grain. Under the second-order schedule, the first fixed-ratio of size n completed after 20 minutes had elapsed was reinforced with food: SO FI 20-min (FR n). Under the conjunctive schedule, the first response made after 20 minutes had elapsed was reinforced only if n-1 responses had been emitted during the interval: conj FI 20-min FR n. The size of the fixed-ratio requirement was increased over conditions from 1 (A fixed-interval), to 30, to 100, to 300 responses. Table I presents the order of schedule arrangements and the number of sessions for each condition in experiment I.

The conjunctive and second-order schedules were presented as two components of a multiple schedule, each component was associated with a different discriminative stimulus, the conjunctive schedule with a blue keylight and the second-order schedule with a red keylight. Food was presented at the completion of each schedule requirement and terminated the component. The components alternated regularly 10 times during an experimental session; between each interval there was a 4-minute time out (TO) during which the experimental chamber was darkened and the key electrically inoperative. The purpose of this procedure was to reduce possible interactions between the two component performances as indicated in previous experiments (Staddon & Innis, 1969; Zeiler, 1972).

Performance measures included overall response rates, quarter-life values, and a measure of fixed-ratio patterning. Quarter life is the time (expressed as percent of the interval value) taken to emit one-fourth of the total number of responses for any interval, and is generally a stable index of fixed-interval patterning (Herrnstein & Morse, 1957). Response measures also included the time until the first response (pause time derived

Table I

Schedule Conditions and Sessions

Schedule	Number of Sessions
Experiment I	
MULT FI 20-min FI 20-min	55
MULT CONJ FI 20-min FR 30, SO FI 20-min(FR 30)	40
MULT CONJ FI 20-min FR 100, SO FI 20-min(FR 100)	40
MULT CONJ FI 20-min FR 300, SO FI 20-min(FR 300)	30
Experiment II Procedure 1	
MULT FI 20-min, FI 20-min	40
MULT CONJ FI 20-min FR30:S^{np}, SO FI 20-min(FR30:S^{np})	30
MULT CONJ FI 20-min FR100:S^{np}, SO FI 20-min(FR100:S^{np})	30
MULT CONJ FI 20-min FR300:S^{np}, SO FI 20-min(FR300:S^{np})	25
Procedure 2	
MULT CONJ FI 20-min FR 30:S^{p}, SO FI 20-min(FR30:S^{p})	30
MULT CONJ FI 20-min FR100:S^{p}, SO FI 20-min(FR100:S^{p})	25
MULT CONJ FI 20-min FR300:S^{p}, SO FI 20-min(FR300:S^{p})	25

Table I (Continued)

Schedule	Number of Sessions
Experiment III — Procedure 1	
FI 20-min	90
SO FI 20-min(FR 30:S^P)	40
CONJ SO FI 20-min(FR 30:S^P) FR 3	30
CONJ SO FI 20-min(FR 30:S^P) FR 6	25
CONJ SO FI 20-min(FR 30:S^P) FR 10	25
CONJ SO FI 20-min(FR 30:S^P) FR 17	25
CONJ SO FI 20-min(FR 30:S^P) FR 30	20
Procedure 2	
SO FI 20-min(FR 100:S^P)	30
CONJ SO FI 20-min(FR 100:S^P) FR 2	25
CONJ SO FI 20-min (FR 100:S^P) FR 3	25
CONJ SO FI 20-min (FR 100:S^P) FR 6	25

from cumulative records) and the time between reinforcer presentations (intereinforcer time). Fixed-ratio pattering was assessed by cumulative records. Conditions were in effect until responding had stabilized, as judged from the cumulative records. Quarter-life values were judged to be stable when the values from the last five sessions did not deviate $\pm$ one standard error of the mean of that condition.

In this and the following experiments, means and standard errors for quarter-life values, overall rates, and intereinforcer times are based on the last 7 to 10 sessions of each condition. Data derived from the cumulative records (pause time) were obtained from the last three sessions of an experimental condition.

Results

During all three experiments, variability measures used were one standard error of the mean. Differences were defined to be non-chance differences if the measures were beyond $\pm$ one standard error of the mean.

The left panels of Figures 1, 2 and 3 show that adding a ratio requirement (FR30, FR100, and FR300) to a fixed-interval schedule increased overall rates of responding. This increase in rate was the only significant effect observed during the experiment. The trends in mean overall response rates will be described subsequently. Circles indicate the blue (FI 20-min or conjunctive schedule) component; triangles show the red (FI 20-min or second-order schedule) component. The bars indicate one standard error of the mean. For one bird, P8, whose overall rate in the red (FI 20-min) component was higher than the blue (FI 20-min) component, overall mean rates remained the same when the FR30 requirement was added as a unit

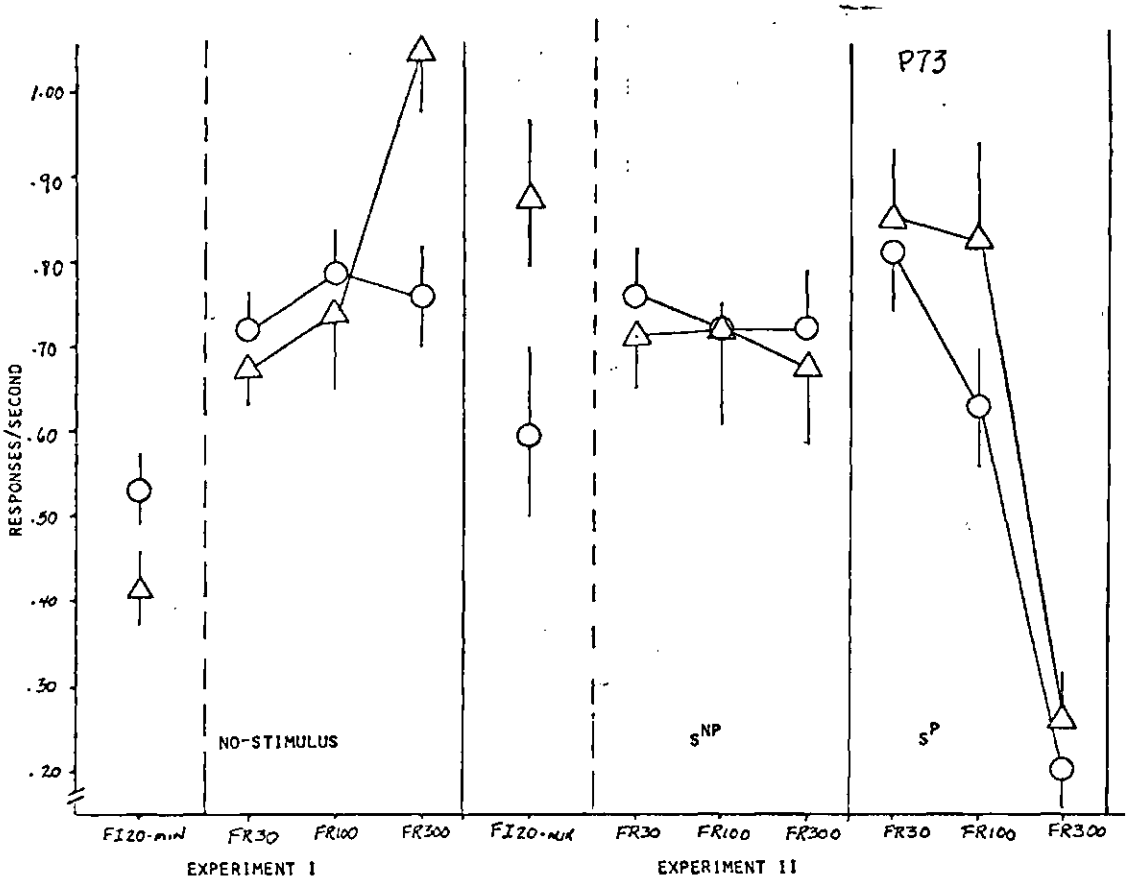

Figure 1. Mean Overall Rates For P73 As A Function Of The Fixed-Ratio Size. Left Panel Represents Experiment I, The No-Stimulus Condition; Middle Panel Is Experiment II, Procedure 1 (S^{np}); Right Panel Is Experiment II, Procedure 2 (S^{p}). Circles Are The Conjunctive Schedule; Triangles Are The Second-Order Schedule. Lines Are One Standand Error Of the Mean.

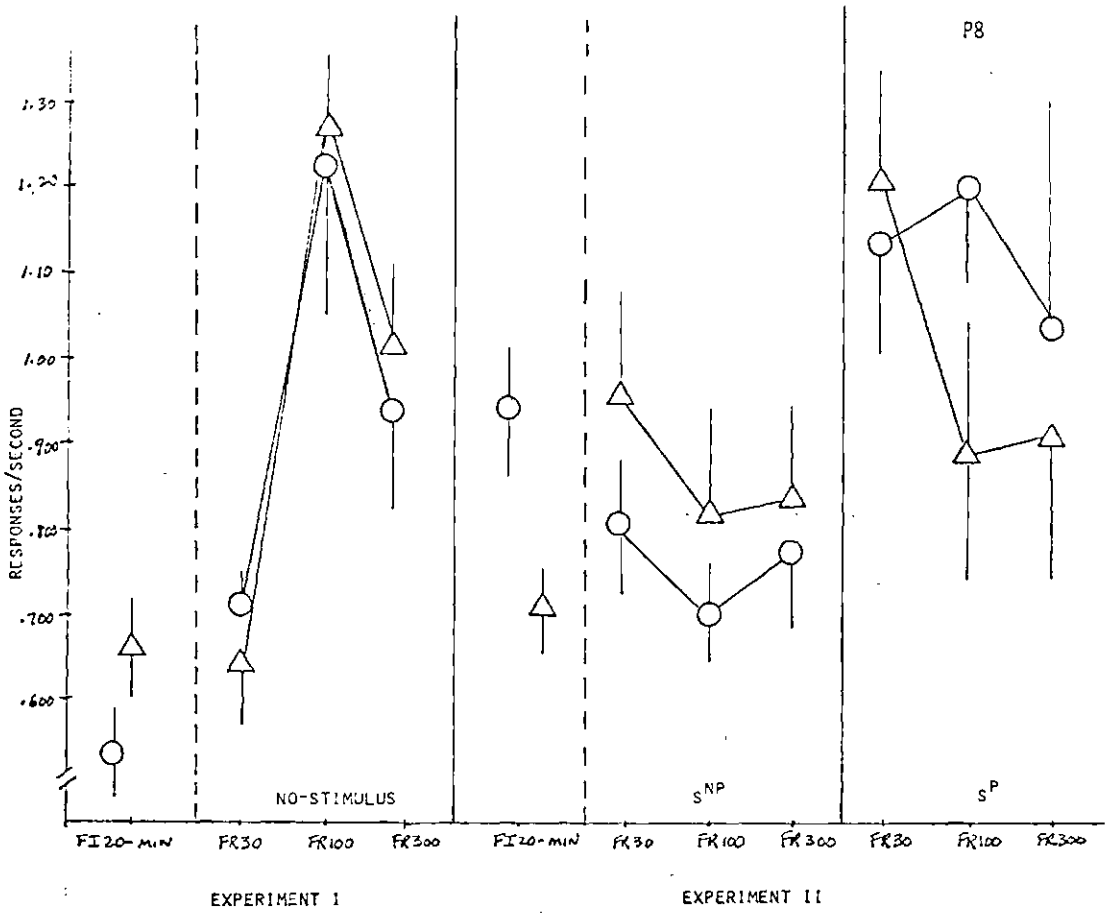

Figure 2. Mean Overall Rates For P8. See Figure 1 For Details.

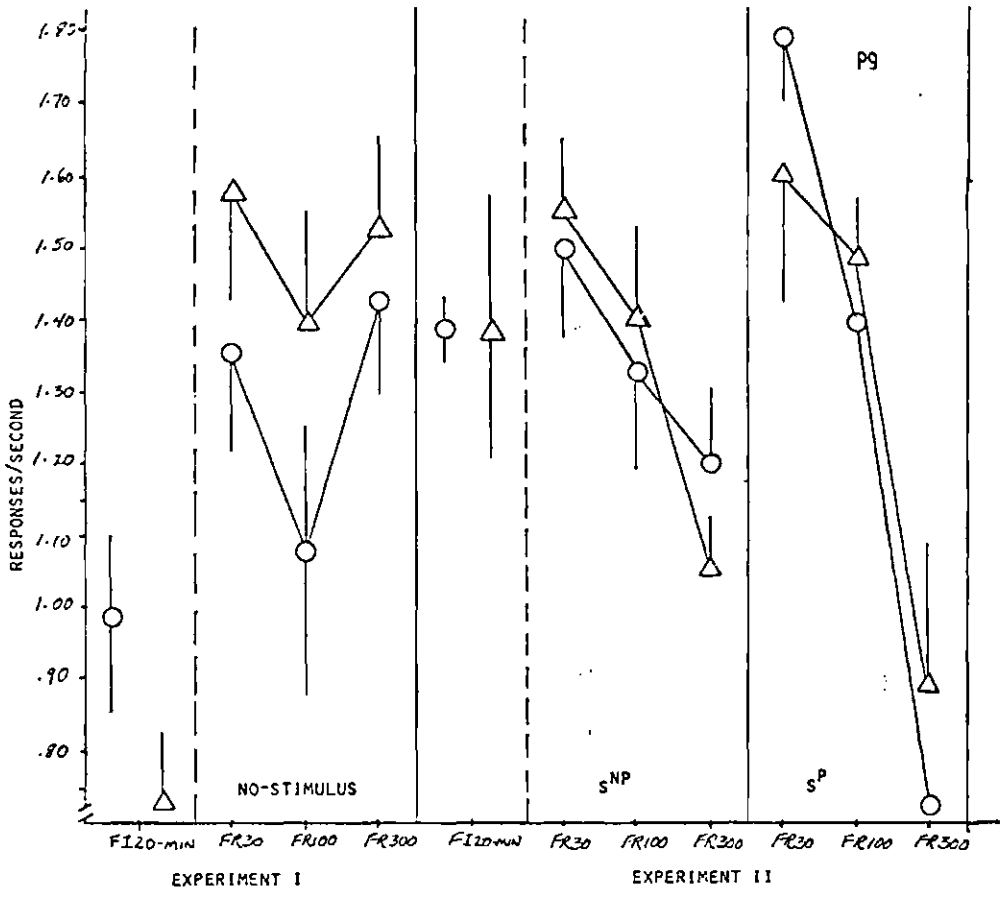

Figure 3. Mean Overall Rates For P9. See Figure 1 For Details.

schedule under the second-order fixed-interval schedule. When the ratio requirement was increased to FR100, P73 and P8, both moderate-rate birds, again increased their overall response rates, but absolute changes in rate for P73 were small. On the other hand, for P9, a high-rate bird, overall rates decreased. When the ratio requirement was increased to FR 300, P8's overall rate decreased in both the conjunctive and the second-order schedules, while P73's rates decreased in the conjunctive schedule, again increasing in the second-order schedule component. P9's rates increased after a decrease in rate under the FR 100 condition. Although in the present and following experiment (II) there were few significant differences in rates between the conjunctive and the second-order schedule. When they did occur, it was at the highest value of the ratio requirement.

The left panels of Figures 4, 5 and 6 show the mean quarter-life values for all conditions for the no-stimulus procedure i.e., no brief stimuli were presented, (Experiment I) for P73, P8 and P9 respectively. In general, the quarter-life values for the conjunctive schedule were less than that of the second-order schedule component. Any apparent differences were in that direction. The legends are the same as the previous figures. Bars indicate one standard error of the mean.

As the ratio value increased, so did the variability of such measures as the quarter-life value and the overall rate. Inspection of cumulative records demonstrate the reason for the increased variability. Figure 7 shows cumulative records for P73 selected from the last three days of each condition in Experiment I. Since the FI 20-min schedule of food reinforcement was always in effect under both components of the multiple schedule, only the ratio requirement and the brief stimulus designation (when appro-

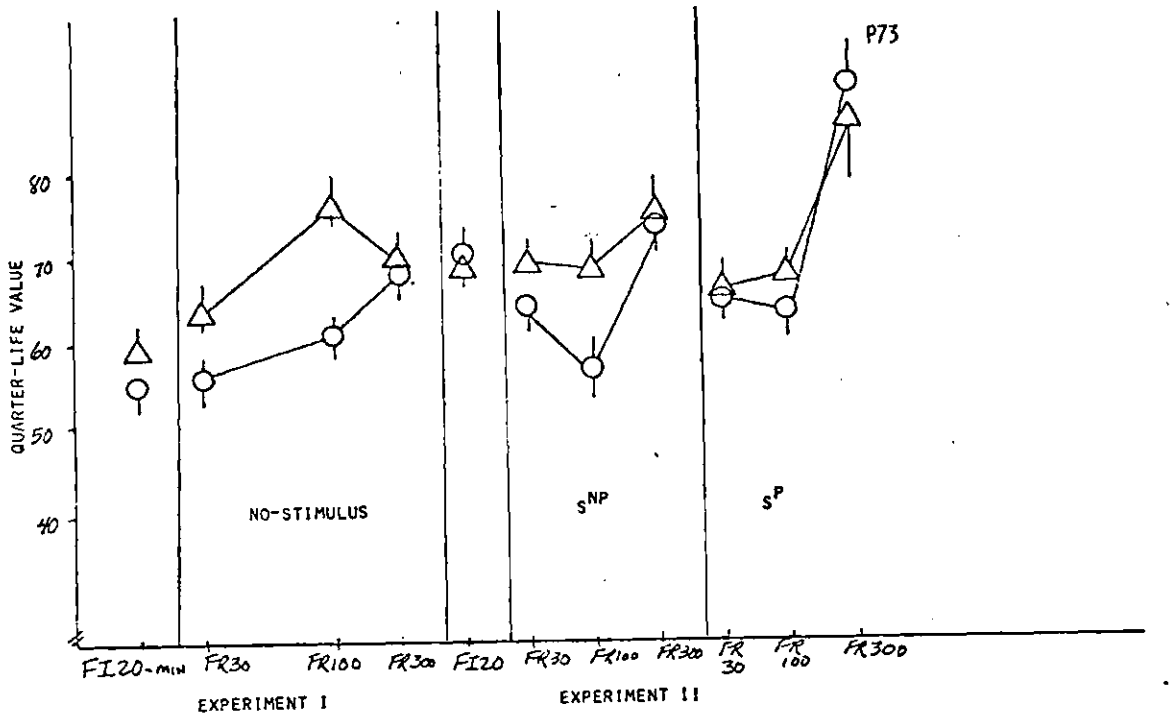

Figure 4. Mean Quarter-Life Values For P73 As A Function Of The Fixed-Ratio Size. Left Panel Represents Experiment I, The No-Stimulus Condition; Middle Panel Is Experiment II, Procedure 1 (S^{np}); Right Panel Is Experiment II, Procedure 2 (S^{p}). Circles Are The Conjunctive Schedule; Triangles Are the Second-Order Schedule. Lines Are One Standard Error Of The Mean.

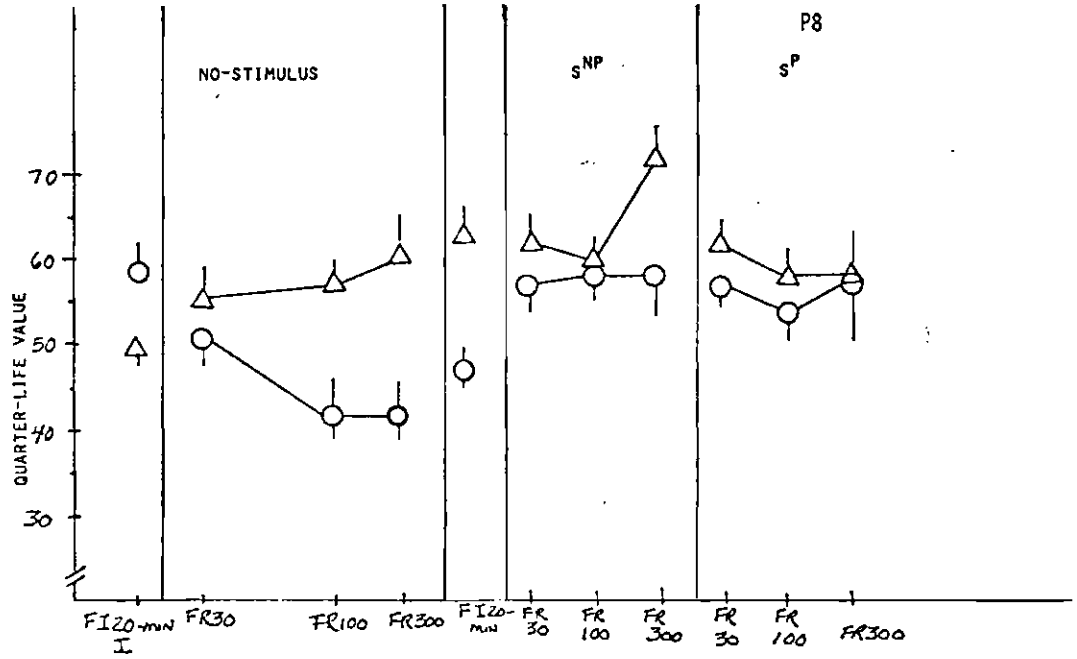

Figure 5. Mean Quarter-Life Values For P8. See Figure 4 For Details.

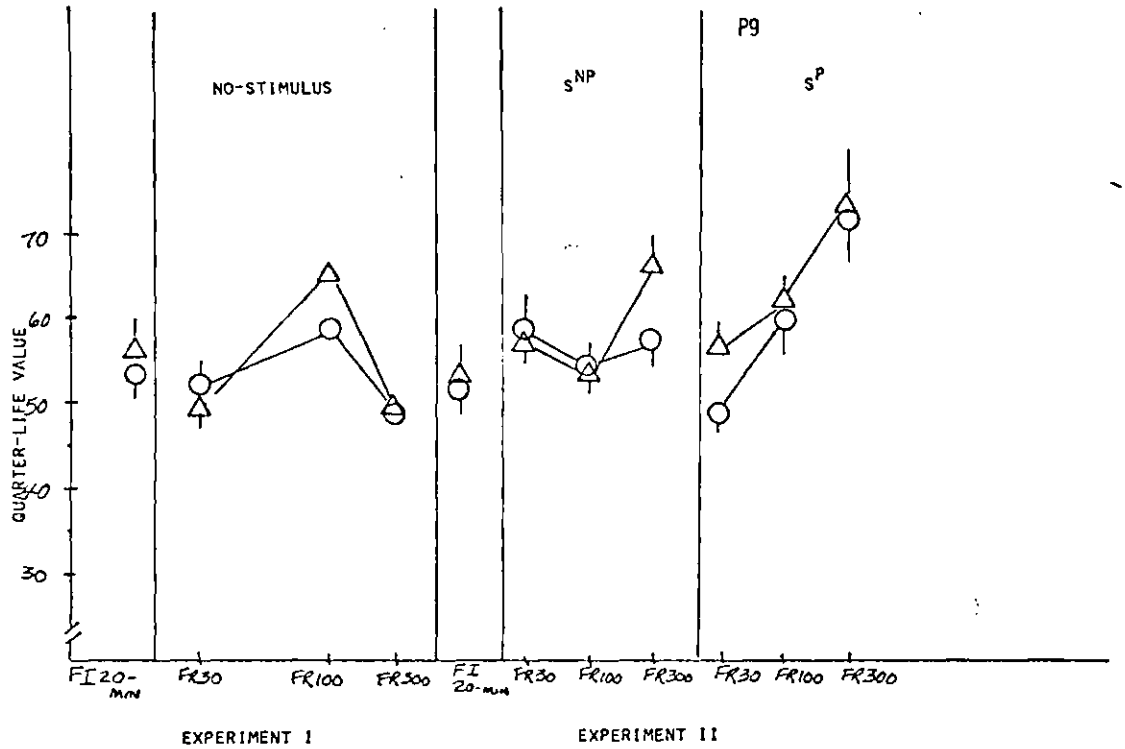

Figure 6. Mean Quarter-Life Values For P9. See Figure 4 For Details.

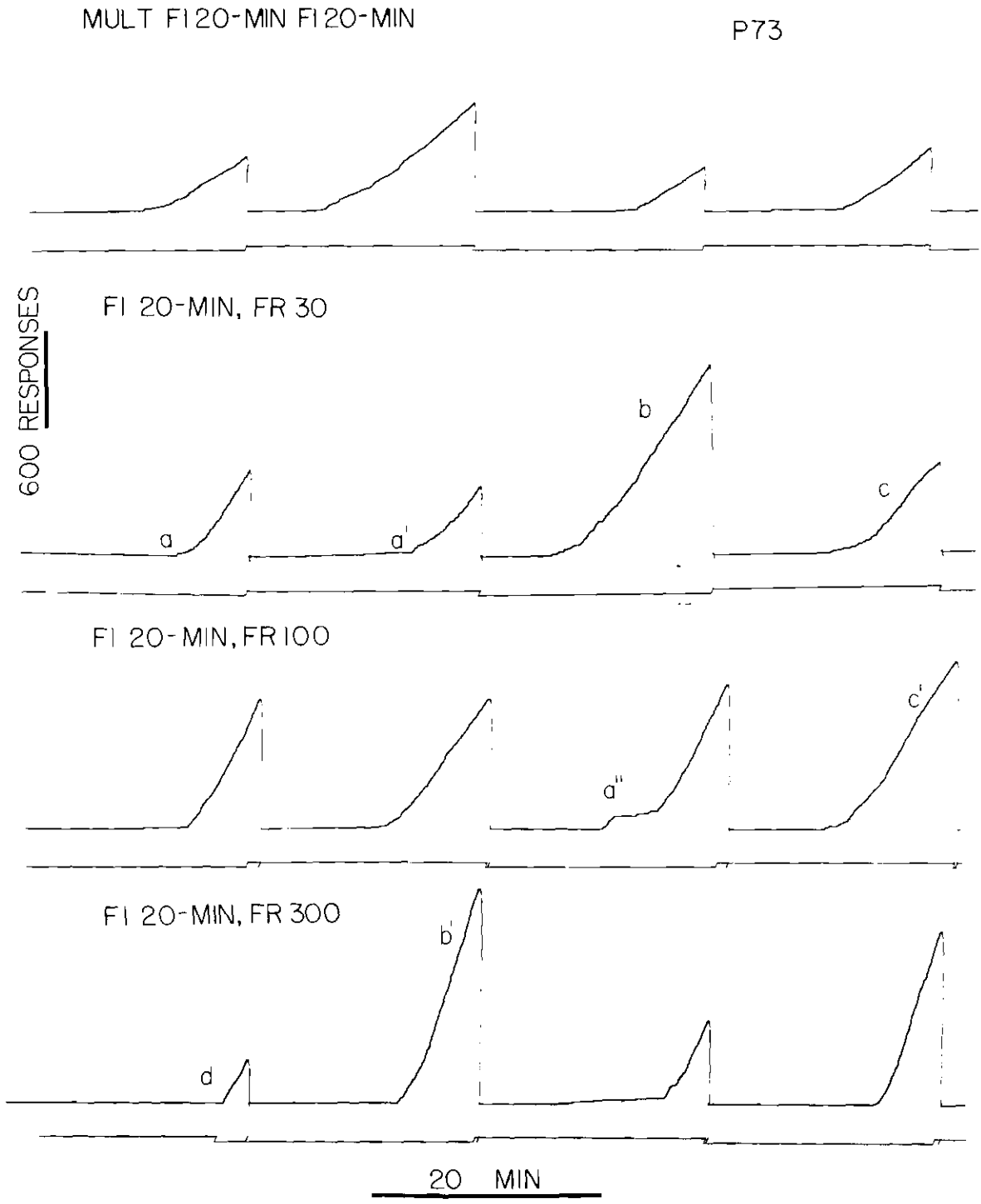

Figure 7. Cumulative Records For P73, Experiment I. Top Row: MULT FI 20-Min, FI 20-Min; Then FR 30, FR 100 and FR 300 Conditions. See Text for Details.

priate) will be referred to hereafter. The top panel shows the original baseline condition: Mult FI 20-min Fi 20-min; the second panel shows FR 30, thethird panel shows FR 100, and finally, the fourth panel is from the FR 300 condition. The downward displacement of the event pen indicates the red keylight condition (fixed-interval or second-order schedule); the event pen in the up position indicates the blue keylight condition (fixed-interval or conjunctive schedule). Beginning with the FR100 concition, the event pen deflected upward or downward when the 20-min interval had elapsed. These records show that adding a fixed-ratio requirement either as a unit schedule or in a conjunctive arrangement increased overall rates of responding. These incresaes in rates paralleled the increase in response requirement except for the highest value (FR 300) under the conjunctive schedule. At these values, P73 would often pause until the interval had elapsed before emitting the required response, as at D. Both the conjunctive and second-order schedule performance were also characterized by a burst of responding following the pause, as at a, a', and a'', then another pause, followed by sustained responding until the next reinforcer delivery. As the size of the ratio requirement increased, so did the prevelance of the pausing for long periods of time, thus accounting for the increased variability in the quarter-life values and overall rates of responding. There was one aspect of the performance of all three birds, especially P73 and P8, which distinguished the performance under the two schedules. Once responding had begun, whether or not there was a second pause during the interval, responding under the conjunctive schedule often showed a negative acceleration during the middle and terminal segments of the interval, such as at c and c'. Contrasted with

this was the positively increased responding during these same segments under the second-order schedule, as at b and b',

The pattern of responding for P9 was altered in a slightly different manner once the ratio requirement had been added to the fixed-interval schedule, as shown in Figure 8. The top portion is taken from the cumulative records of the original baseline (Mult FI 20-min, FI 20-min) condition. The second portion is from the FR 30 condition, and the third row is from the FR 300 condition. In the second and third records, note the consistant abrupt change in response rates following the pause after reinforcement to a very high rate of responding, followed by a lower, but increasing rate until the reinforcer delivery e.g. at a, a' and a''. This pattern was seen for both the second-order and the conjunctive schedule components throughout experiments I and II. Note also the instances of a burst of responding which approximated the size of the fixed-ratio requirement, followed by a second pause before responding was again initiated under both the conjunctive schedule, e.g. b, and b', which also occured in the second-order schedule.

Figures 9, 10, and 11 present the mean pause time per reinforcer for each bird, i.e., the time until the first response, for P70, P8 and P9, respectively. The stippled bars indicate two determinations of the Mult FI 20-min FI 20-min schedule, I is the first condition, Experiment I (II is the first condition in Experiment II). The white bars are the mean pause time for each bird under the three parameter values of the ratio. Lines indicate one standard error of the mean. The top figures are values from the second-order schedule, thebottom figure represents values from the conjunctive schedule. All three birds' average pause time increased

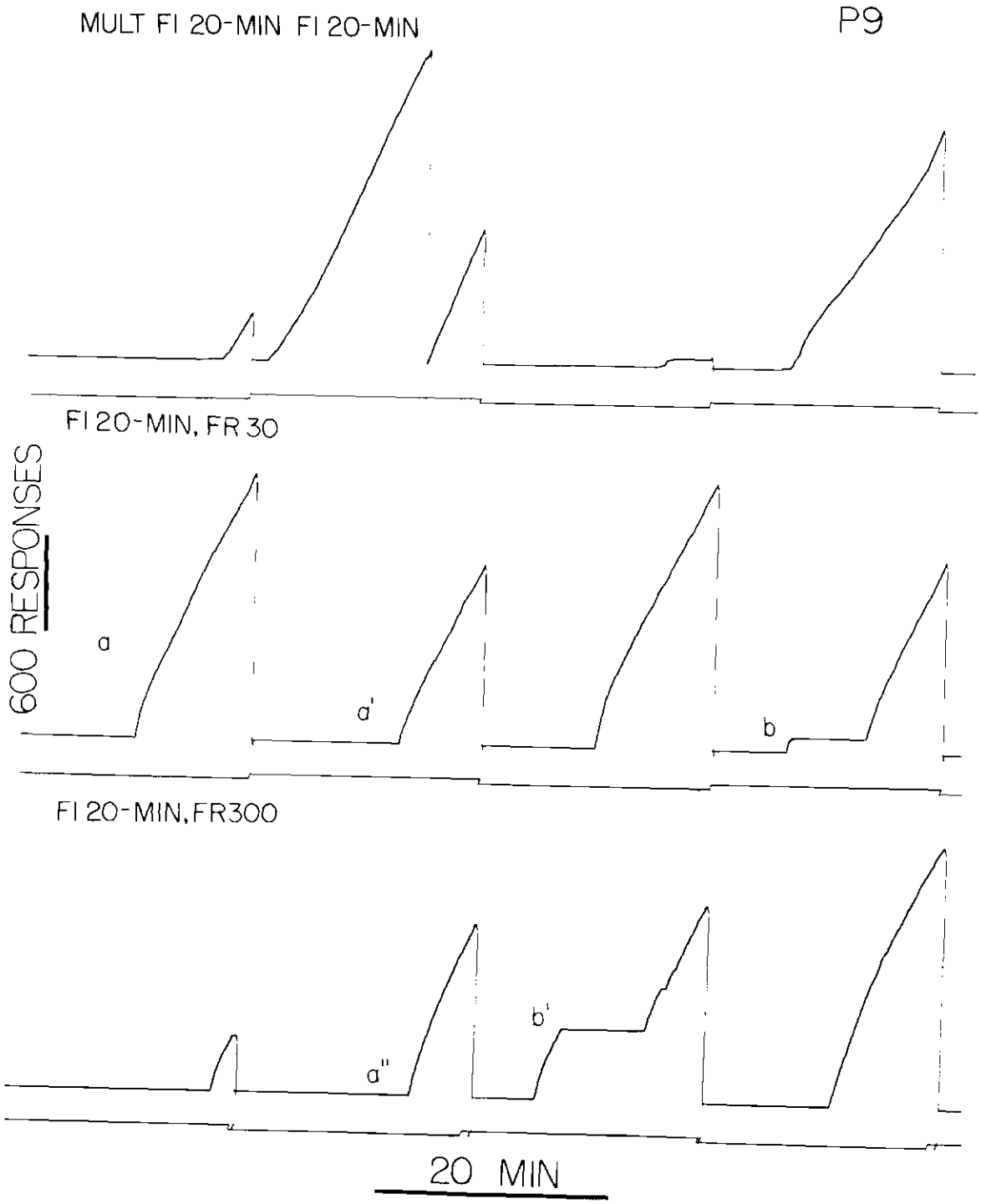

Figure 8. Cumulative Records For P9 From Experiment I. The Top Row Was Chosen From the MULT FI 20-Min,FI 20-Min Condition; Second Row From The FR 30 Condition; Third Row From the FR 300 Condition.

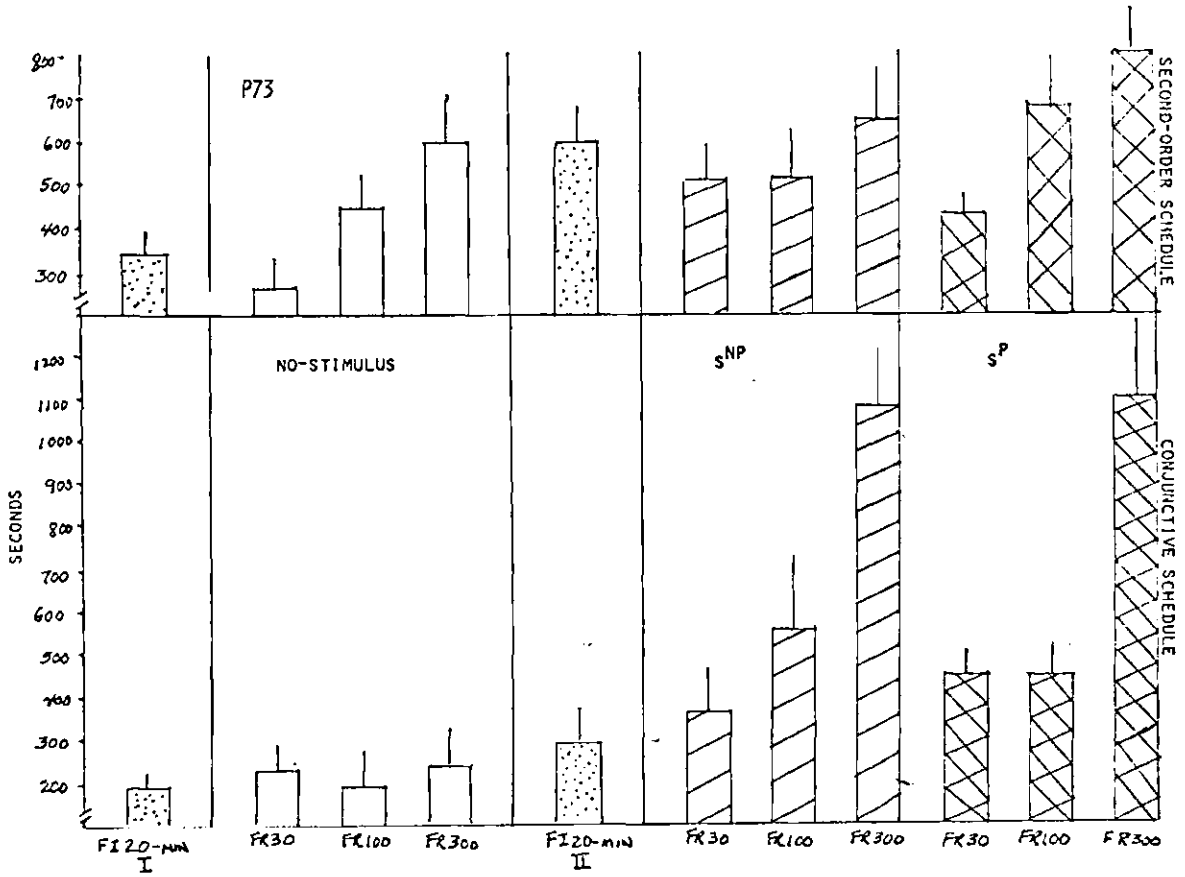

Figure 9. Mean Pause Time Per Reinforcer For P73. Stippled Bars Are the MULT FI 20-Min,FI 20-Min Condition; White Bars Are The No-Stimulus (Experiment I) Condition; Single-Hatched Bars Are The S^{np} Condition; Double-Hatched Bars Are The S^{p} Condition. The Top Figure Is The Second-Order Schedule; Bottom Figure Is The Conjunctive Schedule. Lines Are One Standard Error Of The Mean.

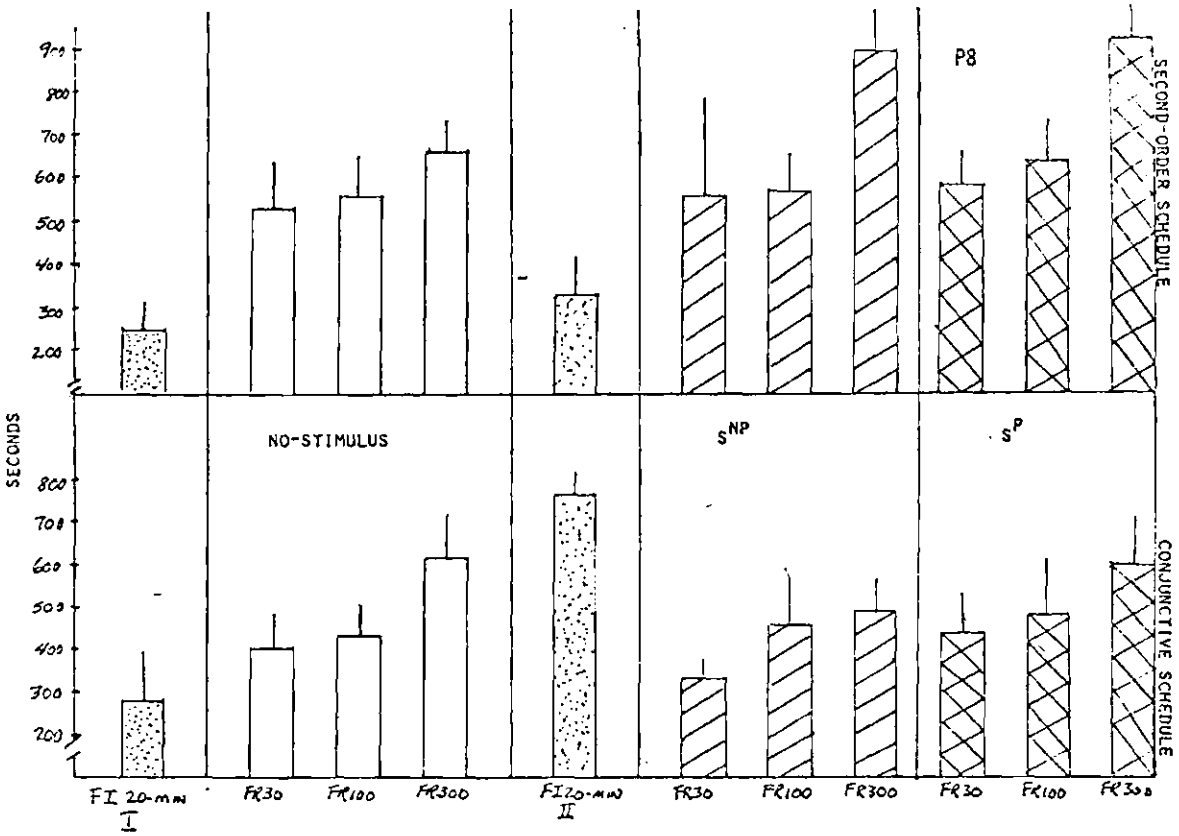

Figure 10. Mean Pause Time Per Reinforcer For P8. See Figure 9 For Details.

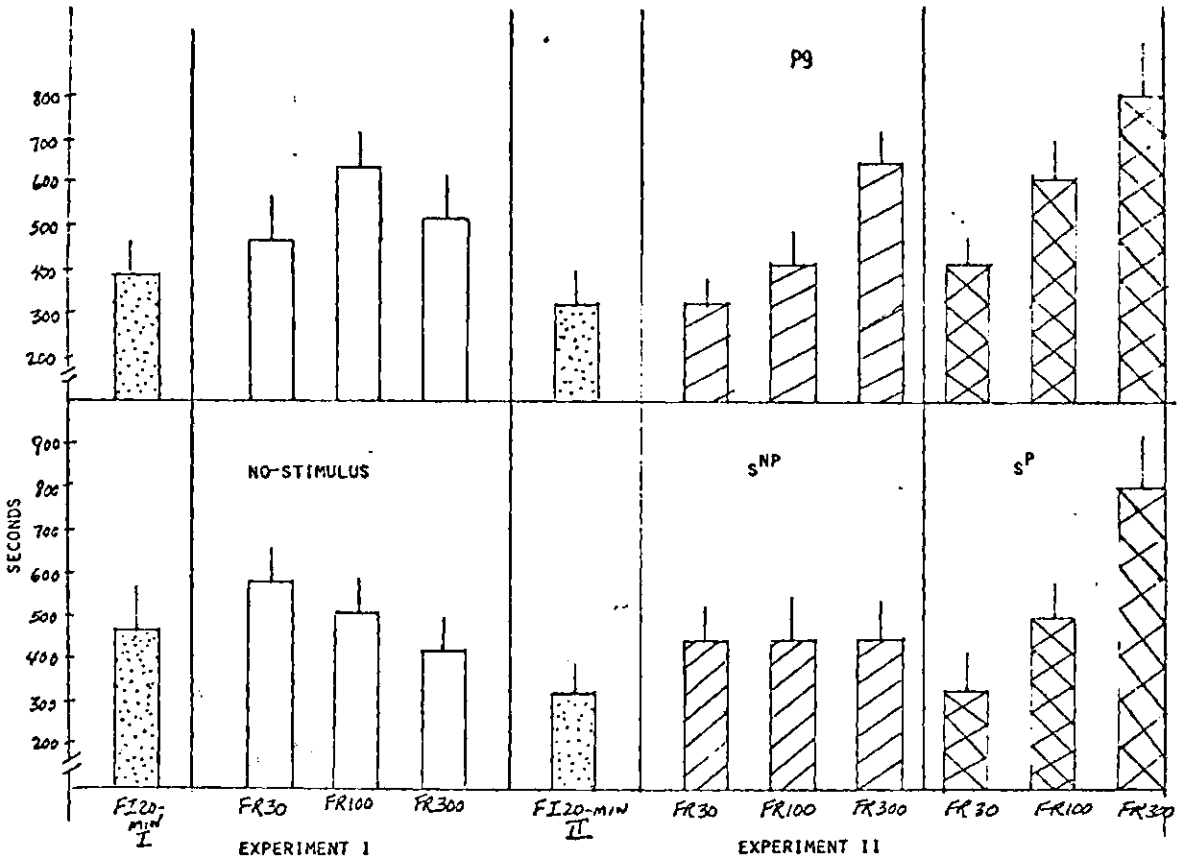

Figure 11. Mean Pause Time Per Reinforcer For P9. See Figure 9 For Details.

as the unit schedule of the second-order schedule increased. Note that P9's pause time then decreased under the FR 300 condition. At the two larger values of the ration, pause time increased over the baseline value (I, Mult FI 20-min FI 20-min). Pause time was always less under the conjunctive schedule component compared to the second-order schedule, except for P9 under the FR 30 condition. P9 responded at such a high rate thus this small ratio requirement was seldom met after the interval elapsed. Pause time under the conjunctive schedule either did not increase with increasing ratio size (P8, P73) or decreased (P9). However, P73's pause time did increase under the conjunctive schedule, FR 300 condition, since the bird would often pause the length of the interval before completing the ratio requirement (see Figure 7, bottom panel, at d).

Figures 12, 13, and 14 present the mean inter-reinforcer time for all three birds under all conditions of experiments I and II. The legends are the same as the previous figur. The time between reinforcers increases as the unit schedule increased under the no stimulus condition. (There was a slight decrease in inter-reinforcer time for P73 under the FR 300 condition). The inter-reinforcer time did not increase under the conjunctinve schedule, except at FR 300 for P73 and P8. Although P73's pause time had increased under this condition (Figure 9), the increasewas small since P73 met the ratio requirement soon after the interval elapsed. P8, on the other hand, would begin responding, but then pause until after the interval elapsed to complete the response requirement. This had the effect of increasing inter-reinforcer time for P8, without appreciably increasing pause time (see below, Figure 16).

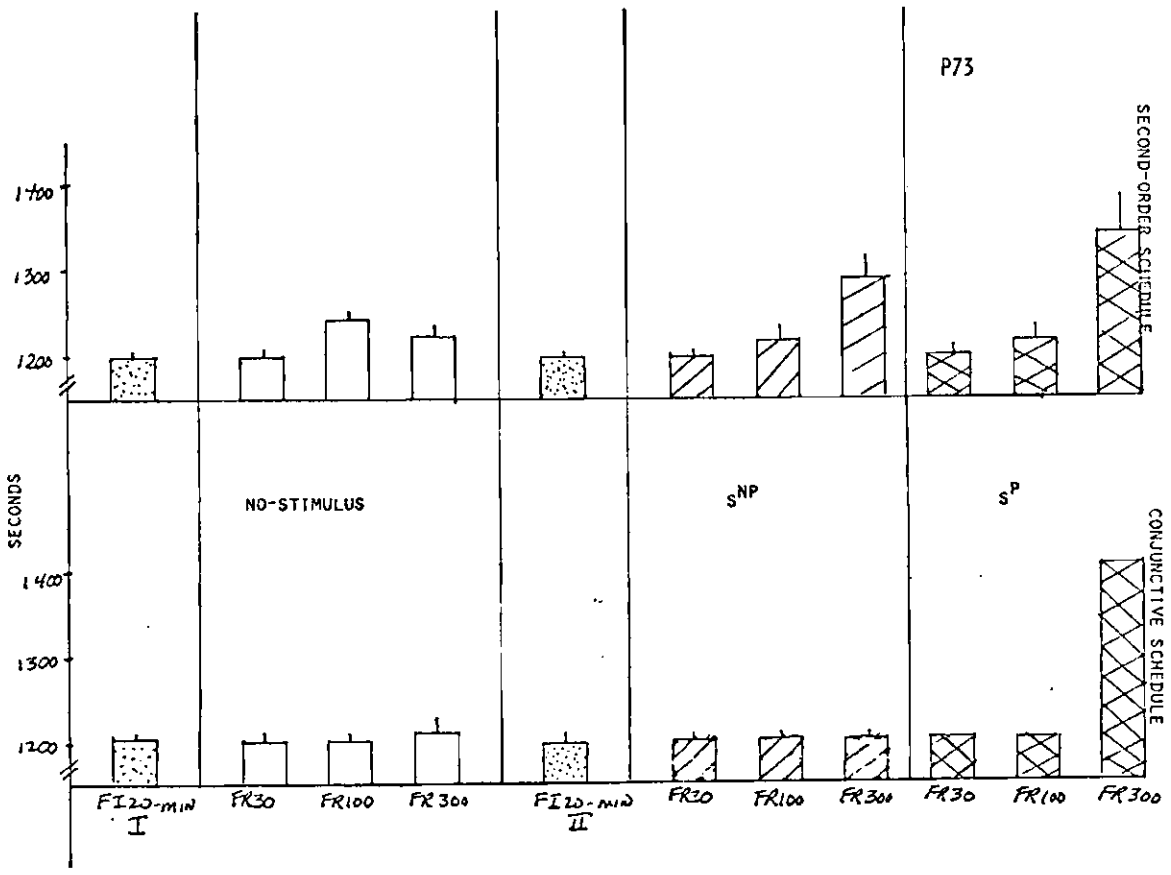

Figure 12. Mean Interreinforcer Time Per Reinforcer For P73. Stippled Bars Are The MULT FI 20-Min, FI 20-Min Condition; White Bars Are The No-Stimulus Condition (Experiment I); Single-Hatched Bars Are The S^{np} Condition; Double-Hatched Bars Are The S^{p} Condition (Experiment II). Top Figure Is The Second-Order Schedule; Bottom Figure Is the Conjunctive Schedule. Lines Are One Standard Error Of The Mean.

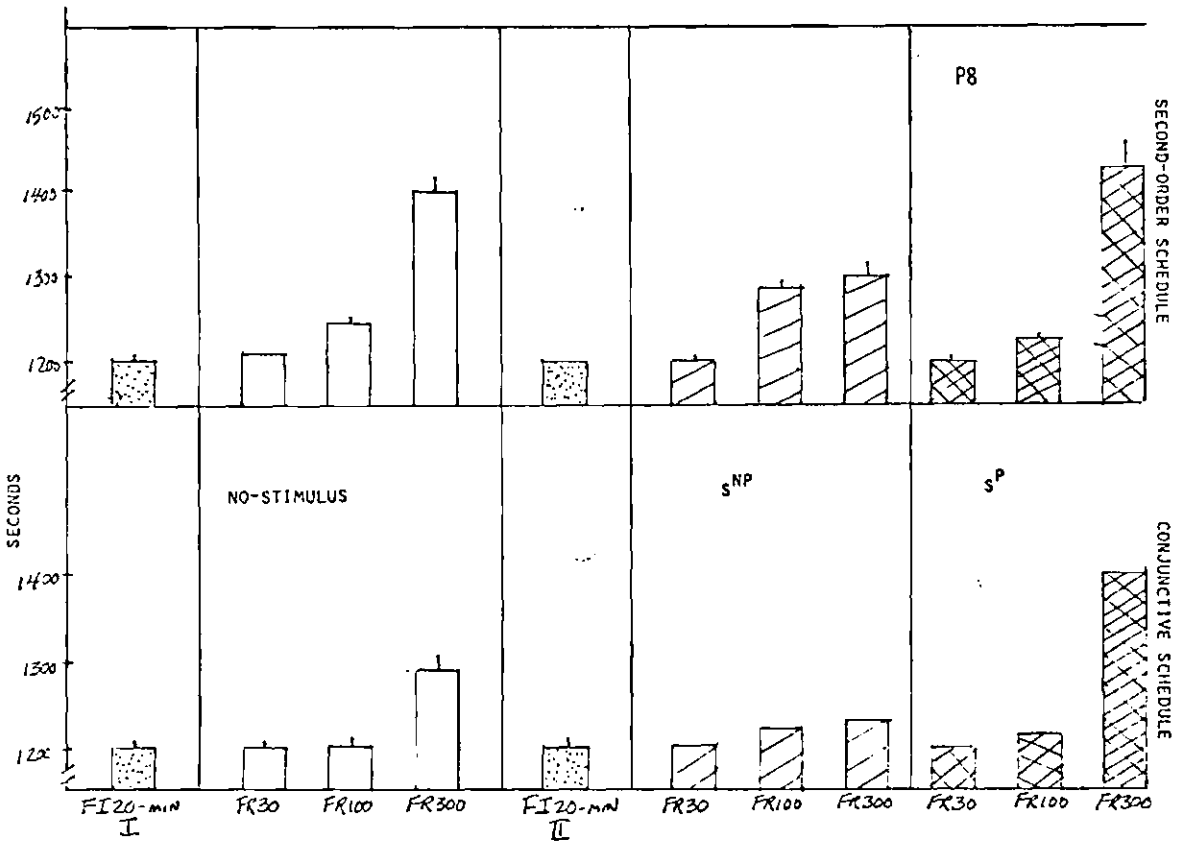

Figure 13. Mean Interreinforcer Time Per Reinforcer For P8. See Figure 12 For Details.

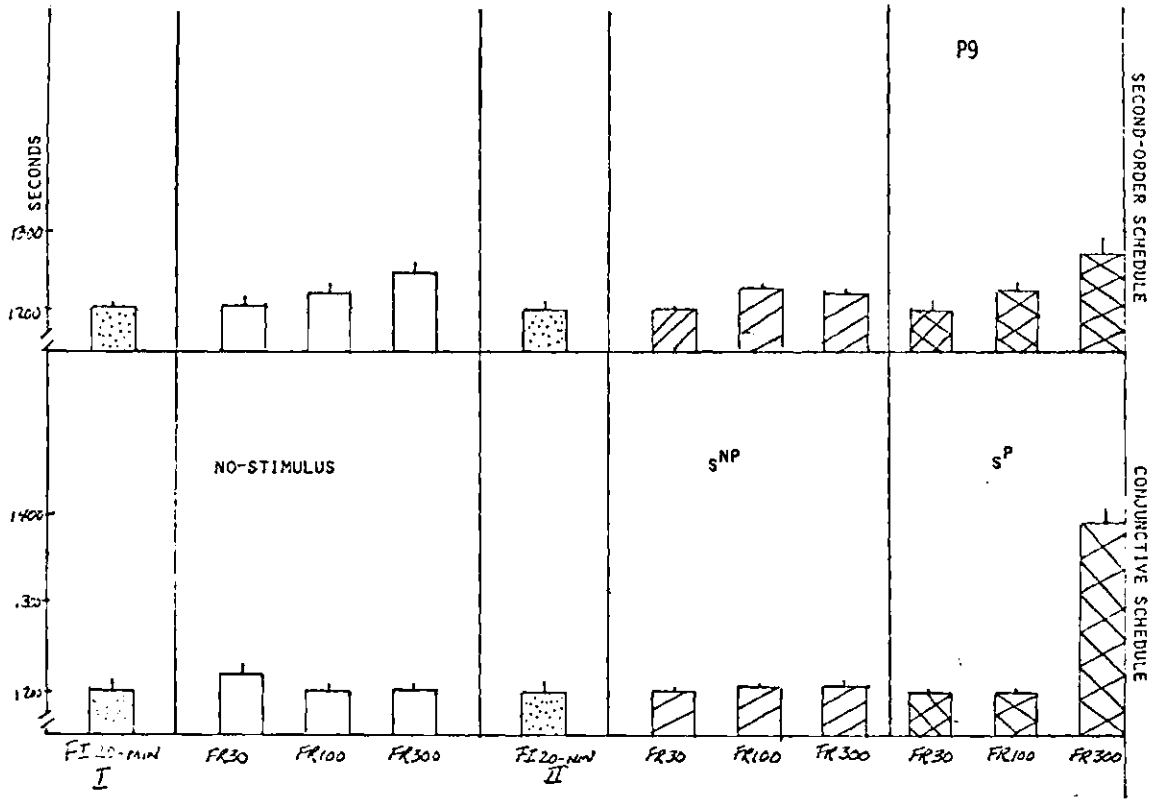

Figure 14. Mean Interreinforcer Time Per Reinforcer For P9. See Figure 12 For Details.

Discussion

In Experiment I, imposing a ratio requirement in either a conjunctive manner or as a unit schedule requirement considerably increased overall response rates when compared to a simple fixed-interval schedule. These results are contrary to some previous findings. For example, Herrnstein and Morse (1958) found that imposing a conjunctive ratio requirement (FR 100) under a fixed-interval 15-minute schedule decreased average response rates from about woo per interval to less than 100 per interval, and increased the interreinforcer interval from 15 minutes to about 80 minutes. During the course of the present experiments, either in the no-stimulus conditions or the brief stimulus conditions (Experiment II), the overall response rates were always higher than the initial simple fixed-interval rates.

However, the present results do coicide with more recent findings concerning conjunctive FI FR schedules. Barrett (1976) studied the effects of adding a conjunctive adjusting ratio requirement to afixed-interval schedule. That is, the ratio requirement size was determined by the organism's behavior; the earlier in the interval the bird responded, the larger the ratio requirement was set for that interval. Under this procedure, Barrett (1976) found that response rates first increased then decreased over the range of ratio values from 0 to 900. Furthermore, the various patterns of responding engendered by the conjunctive schedule are similar to previous findings. The intervals in which responding was initiated at a high rate and then decreased as the interval elapsed, a pattern common to P9, has been reported in previous conjunctive schedule experiments (Barrett, 1975; 1976; Herrnstein & Morse, 1958). In addition, the occurrence

of variations in patterning is common to conjunctive schedules as well (Barrett, 1975; 1976). At larger ratio values of a conjunctive schedule, instances have also been observed in which the organism paused the length of the interval before meeting the conjunctive ratio requirement (Barrett, 1976; Herrnstein & Morse, 1958), as were seen in the present experiment. Finally, Barrett (1976) found instances of patterning which were like those engendered in many intervals during this experiment in which a burst of responding would be followed by a pause.

The rate enhancement found under previous second-order schedule, SO FI t (FR n:S) when compared to a simple fixed-interval has been attributed to the presentation of the brief stimulus terminating theunit schedule or to the reinforcement of the ratio performance (Bradford & Marr, 1976). However, very large increases in overall rates were found in the present experiment under the no-stimulus procedure. The patterns of responding engendered under the second-order schedule were very similar to those seen under the conjunctive schedule component. Only one bird, P9, maintained consistently higher rates under the second-order schedule in the no-stimulus procedure. The only consistent difference between the conjunctive and the second-order schedule components was in the final segments of the interval. Under the conjunctive schedule, after the initial burst of responding, a negatively accelerating rate was often seen in the middle and terminal segments of the interval. This is possible becuase of the temporal relationship of the response requirement to the reinforcer. The second-order schedule, FI t (FR n) provides a reinforcer for the first fixed ratio of size n that is completed after the interval has elapsed. Morse (1966A) has demonstrated that shorter IRTs (Inter-response times) will be different-

ly reinforced on ratio as compared to interval schedules; the terminal IRTs in fixed-interval shcedules are likely to be longer than the ones immediately preceding it (Dews, 1969 ; Ferster and Skinner, 1957). The increasing response rates in the terminal segments of the second-order schedule could be explained by the reinforcement of shorter IRTs, a characteristic of fixed-ratio responding. The higher rates in the terminal segments did not result in higher overall rates in the second-order schedule since the pause time under the conjunctive schedule was usually shorter. This reinforcement of shorter IRTs could account for the higher rates seen under the second-order schedule when compared to the simple fixed-interval schedule.

Post-reinforcement pauses were longer under the second-order schedule and the conjunctive schedule in experiments I, compared to the original FI 20-minute schedule. One reason is that early "probes" i.e., isolated bursts of responding early in the interval (Cumming & Schoenfeld, 1958) almost never occurred under either complex schedule. In addition, under both schedules, the larger the ratio requirement, the higher probability of lengthening the inter-reinforcer time. Post-reinforcement pause size increases on with longer durations of intervals (Schneider, 1969; Innis & Staddon, 1971; Shull, 1971). This may, part, account for the generally longer pause time in the second-order schedule component when compared to the conjunctive schedule component. If the ratio requirement were completed before the interval elapsed under the conjunctive schedule, the first response thereafter would be reinforced. Under the second-order schedule, the ratio requirement always had to be completed after the interval elapsed, increasing the interreinforcer time with increased size of the unit schedule.

Because overall response rates were increased considerably under both complex schedules even with the samllest ratio requirement, the conjunctive ratio requirement was most often met prior to the termination of the interval. It was not until the ratio requirement was increased to 300 that all three birds began to complete the response requirement after the interval ahd elapsed for both the conjunctive and the second-order schedules. The resiliency of the performance under the conjunctive schedules component may have been affected by another variable. There is a possibility of an inductive effect between the two components of the multiple schedule (Reynolds, 1961). Under a multiple schedule the response rates in one component may be affected by the particular schedule programmed in the other component (in this case, the second-order schedule) (Nevin, 1973). The four minute time-out (TO) was an attempt to eliminate such interactions, but as indicated below, this procedure may not have eliminated all interactions between the two components.

To summarize, both conjunctive and second-order schedules maintained responding up to a ratio requirement of 300 responses. However, the pause time was usually shorter under the conjunctive schedule than the second-order schedule, and negative acceleration of responding was seen only in the conjunctive schedule indicating that the birds were discriminating between the two response requirements.

CHAPTER III

EXPERIMENT II: THE ROLE OF BRIEF STIMULI

Introduction

Stimulus Functions.

The dependensices prescribed by a schedule of reinforcement and the organism's history determine what effects a consequent stimulus will have. Morse and Kelleher (1970) have stated that the status of a particular event may depend less upon the event itself than upon how it is scheduled. For instance, a response-dependent shock may serve as a punisher, a negative reinforcer, or a positive reinforcer, depending upon its schedule of presentation and the organism's history. Furthermore, the effects of additional variables upon performance may, to a large extent be determined by the type of schedule controlling the behavior. Dews (1955) found that dose levels of pentobarbital that drastically reduced rates of responding under a fixed-interval schedule had relatively little effect upon performance under a fixed-ratio schedule. Consequently, the events which affect behavior must be identified and defined in terms of a particular situation (Morse & Kelleher, 1970). For instance, unconditioned reinforcers have traditionally been thought of as stimuli which are reinforcing for all members of a species, without regard to that organism's history (Gollub, 1976). Yet, dry food in the mouth of Pavlov's dogs was not an effective eliciting stimulus if the dogs had been exposed only to milk (Gollub, 1976); likewise, food tends to be reinforcing only if the organism has been de-

prived. Conditioned reinforcers are stimuli that have come to have reinforcing effects through a history of association with unconditioned reinforcers. But as Gollub (1976) points out, no stimulus is a reinforcer completely devoid of that organism's history. Thus, the difference between unconditioned reinforcers and conditioned reinforcers with regard to the organism's history, is only one of degree. The term conditioned reinforcement is usually reserved for stimuli whose conditioning history has been specifically arranged by the experimenter (Gollub, 1976).

Since the functions of consequent stimuli are defined by the effects which they have upon behavior, in order for an event to be called a reinforcer of a particular response, it must be demonstrated that the behavior is sustained by the presentation of the stimulus.

Brief Stimuli in Second-Order Schedules.

An important factor in determining rates and patterns of responding under second-order schedules is the presence or absence of stimulus changes at the termination of each unit schedule requirement of the second-order schedule. If a brief stimulus follows all the units, including the one terminating in the reinforcer, e.g., it is designated a paired stimulus (S^P). However, the brief stimulus may terminate all the components except the final unit ending in food presentation. In this case, the brief stimulus is not directly associated with the reinforcer and is designated a non-paired stimulus (S^{NP}). As in the case of other stimuli, the role of a brief stimulus terminating second-order schedule units can be defined in relation to its effects on behavior. A well documented phenomenon is that brief stimuli may demonstrate reinforcing properties, especially if the brief stimulus is paired with food. Kelleher (1966) investigated a

number of fixed-ratio second-order schedules, under conditions of no stimulus or a paired stimulus terminating each fixed-ratio completed. Kelleher found that the presentation of a paired brief stimulus not only produced patterning characteristic of food-maintained performances within the units, but also engendered higher overall rates of responding when compared to the no-stimulus procedure.

Malagodi, Deweese and Johnston (1973) compared the performance engendered under a paired and non-paired brief stimulus procedure, where the brief stimulus was presented at the completion of a fixed-interval 2-minute schedule (FI 2-min). Executing two such intervals resulted in food presentation: SO FR 2(FI 2-min). They found substantially more within-unit patterning, i.e., a pause followed by increased responding until the next brief stimulus presentation, during the first FI 2-min unit, and higher overall rates of responding when the brief stimulus was paired with food. However, overall response rate is not necessarily the best indication of response strength. Byrd and Marr (1969) investigated the performance engendered by the schedule, SO variable ratio (VR) 12 (FI 20-min;S). That is, on the average, every 12th FI 2-minute schedule performance was reinforced by food presentation. They found that the non-paired brief stimulus engendered higher overall response rates, but they attributed this to the fact that there was substantially more pausing early in the fixed-interval units under the paired brief stimulus conditions. Thus, the effects of brief stimuli observed under second-order schedules may be characterized by enhancement in the response rates within unit schedules or unit schedule patterns maintained by the presentation of the brief stimuli that are identical to those patterns of responding maintained

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by food presentation.

The role often assigned to brief stimuli as a result of these enhancing effects is that of a conditioned reinforcer. At the present time, however, the necessary and sufficient conditions to establish a stimulus as a conditioned reinforcer remain elusive (Kelleher & Gollub, 1962: Gollub, 1976). But the data concerning the paired stimuli are clear: they exert control over responding by either increasing rates of responding or generating schedule-characteristic patterns of responding within unit components (Byrd, 1972; DeLorge, 1967; 1969; Kelleher, 1966A; 1966B; Marr, 1969; thomas & Stubbs, 1969). On the other hand, some investigators have found enhanced responding or schedule characteristic patterning with non-paired stimuli (Stubbs, 1971; stubbs & Cohen, 1972; Stubbs & Silverman, 1972). In these cases, a <u>discriminative</u> function of the brief stimulus has been emphasized. Stubbs (1971) suggested that when fixed unit components (e.g., FR or FI) are used, there is a fixed period of time between the occurrence of the last brief stimulus and food presentation, and the brief stimulus may thus acquire S characteristics. (an S^{Δ} is a stimulus in the presence of which responding is never reinforce, i.e., an extinction schedule). That is, during the first part of the unit, food is never presented, and thus the organism pauses before responding. If the first part of the fixed unit developed S^{Δ} properties, or if the brief stimulus acquired reinforcing properties controlling schedule characteristic patterns, the end result would be similar - a pause after the brief stimulus presentation followed by increased responding. However, the S^{Δ} hypothesis would explain the unit patterning in both the paired and non-

paired conditions.

According to the proponents of the discriminative stimulus hypothesis, in order for a unit performance to develop there must be an exact correspondence between the schedule terminating in the brief stimulus and the schedule terminating in food presentation (Neuringer & Chung, 1967). One way of eliminating this relationship has been to schedule brief stimuli and food presentations independently. This is called a conjoint schedule if the two schedules are operating independently on the same manipulandum; if separate manipulanda are used, it is called a concurrent schedule. However, in studies using this arrangement, the conclusions regarding the performance engendered by these schedules have not always been the same. For instance, Shull et al. (1972) found no evidence for either increased rates of responding or characteristic patterning under a fixed-ratio schedule for brief stimuli presented conjointly with a fixed-interval schedule for food. Contrasted with these experiments are ones in which there was an effect upon performance as a result of the paired brief stimulus presentations. For example, Marr and Zeiler (1974) scheduled a brief stimulus presentation under either a 3-minute fixed- or variable-interval schedule while conjointly presenting food under a 15-minute fixed-interval schedule. They found that both paired brief stimulus schedules enhanced the low rates normally occurring early in the brief stimuli schedules. Zimmerman (1963) scheduled

food presentation for pigeons on one key, while concurrently presenting a response-produced paired brief stimulus on a second key, and found that responding on the second key was maintained over many sessions. In Zimmerman's study, responding was maintained by the brief stimulus associated with food, albeit at lower rates of responding than was maintained by the food producing key, but rates and patterns of responding on the brief stimulus key were appropriate for the schedule in effect. These two experiments present empirical evidence that the brief stimulus and food need not be presented under the same schedule in order for the unit schedule pattern to occur.

The data from the conjoint and the concurrent schedules in which the performances were altered by the brief stimulus presentations suggest that the rate-enhancing effects of the added brief stimuli can best be obtained when the response that produces the brief stimulus is under minimal control of food reinforcement. The clearest sustained effects are obtained when the response never produces food, as in Zimmerman's (1963) concurrent schedule, or are less strongly controlled by food, as in early segments of fixed-interval schedules (Gollub, 1976). Gollub suggests that the brief stimulus may be serving two roles; one, a discriminative stimulus function, since responding immediately following these stimuli are never reinforced; and second, a conditioned reinforcing effect producing rate enhancement. However, the conditioned rein-

forcing effects of the brief stimuli may be overshadowed by the effects of food reinforcement. A relatively long fixed-interval schedule, e.g., a fixed-interval 20-minute schedule, should allow any differential effects of the brief stimuli at the beginning of the interval to be seen.

Goals.

Experiment II investigated the role of brief stimuli in both second-order schedules and conjunctive schedules. The differences between conjunctive and second-order schedules observed in previous experiments may be attributed to the presentation of a brief stimulus terminating the unit schedule performance. If this is the case, the behavior occurring when a brief stimulus terminates each ratio under the conjunctive and the second-order schedules should be different from the performance engendered under the no-stimulus procedure, Experiment I. These changes in performance could be evident in either overall rates or unit patterns when the brief stimulus was added. Furthermore, the conjunctive schedule offers another test of the necessity of congruence between the schedule which produces food and that which produces the brief stimulus. Under the conjunctive schedule, the brief stimulus will terminate a fixed-ratio performance, but without a fixed relationship between the previous brief stimulus presentation and food. The following hypotheses were examined:

H1: The presentation of a brief stimulus at the completion of the ratio requirement of both the conjunctive schedule

and the second-order schedule will not affect responding when compared to the no-stimulus condition (Experiment I).

H2: There will be no difference in performance engendered by paired and non-paired brief stimuli.

H3: The assured fixed-termporal relationship of the brief stimulus and the reinforcer under the second-order schedule will not differentially affect ratio patterning compared to the conjunctive schedule which does not provide a fixed relationship.

Method

Subjects.

The subjects, apparatus and criterion for changing conditions were the same as in Experiment I.

Procedure.

The first procedure of Experiment II introduced the presentation of a brief stimulus at the completion of the fixed ratio, except when the fixed ratio terminated in food, i.e., a non-paired brief stimulus (S^{np}) condition. Table I shows the conditions for Experiment II. Under the conjunctive schedule, a brief stimulus was presented at the completion of the nth response, unless the ratio terminated in food. A non-paired brief stimulus was presented under the second-order schedule at the completion of each fixed ratio of size n. Procedure 2 in Experiment II was to pair the brief stimulus with food (S^{p}) under both the conjunctive and the

second-order schedule components. The brief stimulus was always a change in the keycolor light from blue (conjunctive schedule) to amber, or from red (second-order schedule) to amber for 0.75 seconds. Under the conjunctive schedule the paired brief stimulus terminated every nth response and immediately preceded food presentation. Under the second-order schedule, the paired brief stimulus terminated each nth response, including the one terminating in food.

Results

The Effects of Brief Stimuli.

The middle and left panels of Figures 1, 2, and 3 show overall rates for P73, P8, and P9, respectively. When the fixed-interval schedule was again put into effect after the entire sequence of no-stimulus conditions (Experiment I) overall rates remained at a higher level than the original baseline level (MULT FI 20-min, FI 20-min). Thus the rate-enhancing effect of requiring more responses continued after the extra response requirements were removed. When the non-paired brief stimulus was added in both the conjunctive and the second-order schedules (middle panel) rate changes from the second determination were not as dramatic when compared to the very large increases from the original baseline overall rates of responding. Rates were comparable to the no-stimulus conditions. After the FR 300:S^{np} condition, a number of transition sessions were run while the ratio requirement was decreased to FR 30:S^{np}. Response rates stabilized at the same

level as the initial FR 30:S^{np} condition. Pairing the brief stimulus with food (left panel) produced increases in overall rates for both the conjunctive and second-order schedules at FR 30:S^{p}. However, the variability measures ($\pm$ one standard error of the mean) of the two measures overlapped in most cases. The mean values, however, tended to be higher in the paired conditions, as seen in the figures. In general, increasing the size of the fixed-ratio requirement decreased overall response rates.

The middle and left panels of Figures 4, 5, and 6 show the mean quarter-life values for the non-paired and paired brief stimulus conditions. Again, as in Experiment I, note the increased variability as the size of the ratio requirement was increased, especially under the conjunctive schedule.

Figures 9, 10, and 11 present mean pause time per reinforcer for each bird. That is, the average time until the first response was emitted under the second-order schedule (top panel) and the conjunctive schedule (bottom panel). The stippled bar labeled II is the MULT FI 20-min, FI 20-min schedule, the first condition in Experiment II. The single-hatched bars represent the non-paired brief stimulus conditions (S^{np}), and the double-hatched bars, the paired brief stimulus conditions (S^{p}), under each of the three parameter values (FR30, FR 100, FR300) of the ratio requirement. Lines indicate one standard error of the mean. As in the no-stimulus conditions, the pause time was generally less

under the conjunctive schedule compared to the second-order schedule. The exceptions were again, P9, at the smallest value of the ratio requirement, and P8, under the larger values of the ratio, when that bird began pausing throughout the interval.

Figures 13, 14, and 15 show that the inter-reinforcer time was increased under the second-order schedule in both the non-paired (single-hatched bars) and the paired (double-hatched bars) stimulus conditions as the size of the unit schedule increased (top panel). On the other hand, the time between reinforcers increased very little under the conjunctive schedulein either the non-paired or the paired conditions. The exceptions were at the largest value of the ratio, when increases were often comparable to the second-order schedule.

Paired vs. Non-paired Brief Stimuli.

Fixed-ratio patterning is characterized by a pause followed by a sustained high rate of responding. Figure 15 shows cumulative records for P73, comparing the paired vs. the non-paired brief stimulus conditions in Experiment II (FR 100). Although there was a slight indication of a pause following the brief stimulus presentation under the paired stimulus condition during the second-order schedule (e.g., at a, a', and a"), especially in the terminal segments of the interval, pauses were not evident following the brief stimulus presentation under the conjunctive schedule (event pen in up position) nor the non-paired brief stimulus conditions.

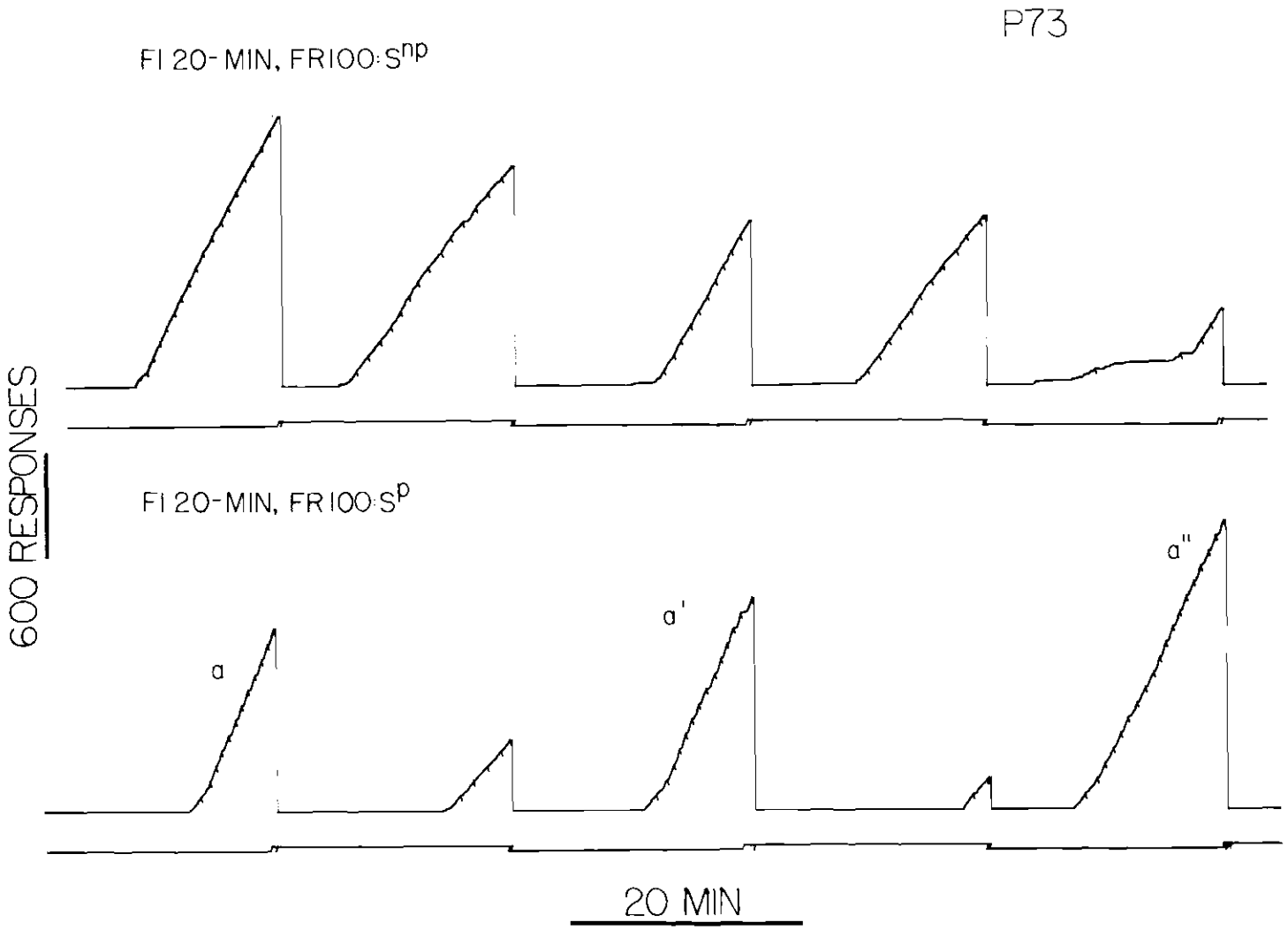

Figure 15. Cumulative Records For P73, Experiment II. Top Record Is From The FR 100:S^{np} Condition; Bottom Record Is From The FR 100:S^{p} Condition. See Text For Details.

P 9 showed no evidence of fixed-ratio patterning under any of the brief stimulus conditions. In contrast to P9, P8 (Figure 16) showed distinct pauses under the paired brief stimulus condition (bottom record) in the second-order schedule (event pen down), e.g., at e and e', that are not present in either the conjunctive schedule component (event pen in the up position) or during the non-paired stimulus conditions (top record). These pauses account for the lowered rate under the paired conditions during the second-order schedule component (see Figure 2). Note also the pattern of a pause, then a burst of responding, followed by another pause under the second-order schedule, e.g., a, and the conjunctive schedule, e.g., at c. At larger values of the ratio requirement under Experiment II, the birds would again sometimes pause the entire length of the interval before emitting the required responses, as in Experiment I, for example, at b (second-order schedule) and d (conjunctive schedule). Under the brief stimulus conditions, after the initial burst of responding, it was common for the birds to pause throughout the interval rather than beginning to respond again, as during the no-stimulus conditions (see, for example, Figures 7 and 8). This was perhaps because the brief stimulus signalled the completion of the response requirement under the conjunctive schedule. The bird would then pause longer than under the no-stimulus procedure before re-initiating responding. If the conjunctive schedule were

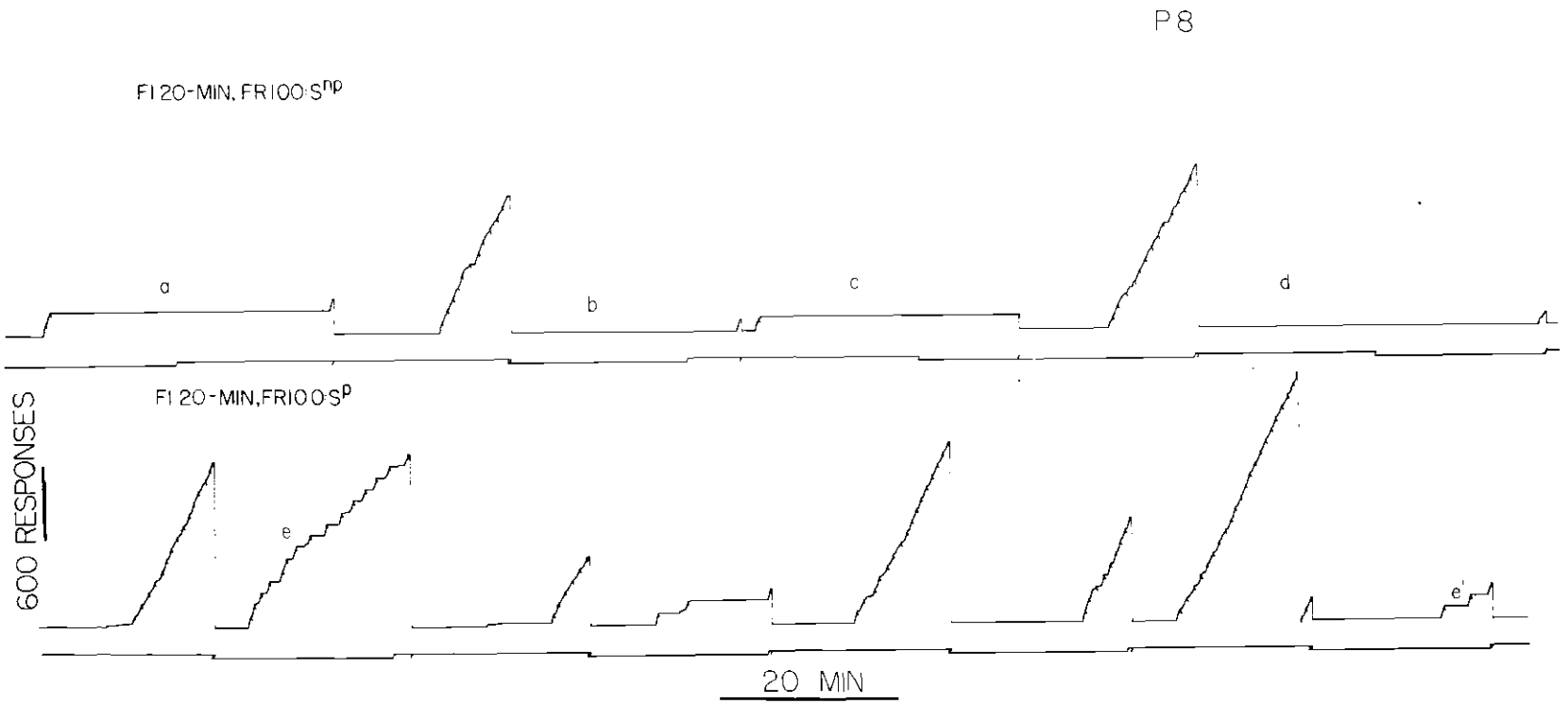

Figure 16. Cumulative Records For P8, Chosen From Experiment II. The Top Record Represents The FR 100:S^{np} Condition; Bottom Record Is From The FR 100:S^{p} Condition. See Text For Details.

in effect, the first response would then be reinforced, as at c. If the second-order schedule were in effect, the bird would continue to respond until the reinforcer delivery, as at a.

Figure 17 shows cumulative records for P9 comparing a no-stimulus condition (FR 30) and a brief stimulus condition (FR 30:S^{np}). These records indicate that the pause time decreased under the brief stimulus conditions, since responding was initiated much earlier in the interval, perhaps because responding during the first segments of the interval now had some consequence, i.e., a brief stimulus presentation. In addition, P9's response rates were so high, the bird seldom came in contact with the conjunctive ratio requirement, and the fixed-ratio unit requirement increased this bird's inter-reinforcer time very little. In addition, when responding was initiated early in the interval, it was at a much lower rate than this bird's characteristic pattern of a very high initial rate.

Discussion

Kelleher (1966b) found when the brief stimulus (S^{p}) was removed from the second-order schedule, FR n(FR t:S^{p}) overall response rates were lower and the within-unit patterning disappeared. In the present experiment, overall rates tended generally to increase from the no-stimulus procedure compared to the fixed-interval conditions. Adding either a paired or a non-paired brief stimulus did not

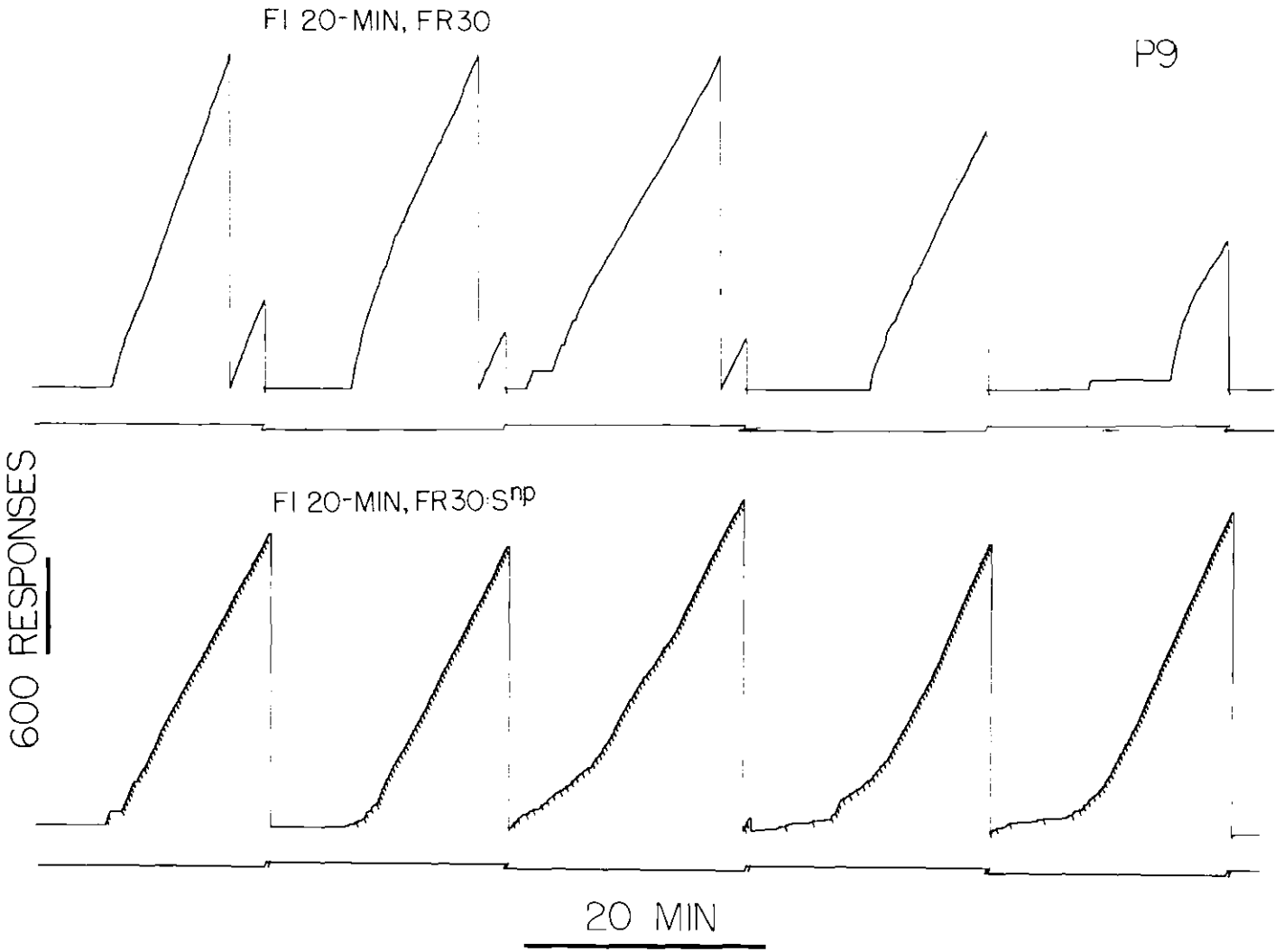

Figure 17. Cumulative Records For P9, Comparing A No-stimulus Condition (Top Record, FR 30, Exp.I) With A Brief Stimulus Condition (Bottom Record, FR 30:S^{np}, Exp. II).

serve to increase rate further in a consistent manner. Response rates did tend to increase slightly when the brief stimulus was paired (FR 30:S^{p}) but these increases were not significant (more than one standard error of the mean from the FR 30:S^{np} condition) for all birds. The rates under the paired brief stimulus procedure decreased as the size of the ratio increased. The only bird that showed distinct patterning with-units was P8. One possible explanation for the lack of characteristic fixed-ratio patterning seen in the paired brief stimulus conditions of second-order schedules previously studied (e.g., Bradford & Marr, 1976; Kelleher, 1966a; Shull et al., 1972) is a possible interaction between the two components of the multiple schedule. Under the conjunctive schedule, the last ratio to be completed was always variable. A variable ratio engenders a constant rate of responding. This suggestion is supported by a careful examination of the cumulative records. Once the brief stimulus had been paired with food, pauses after the brief stimulus presentations within the unit schedules would appear and disappear during the course of a session. The pauses in the conjunctive schedule would appear at various times during the execution of a ratio, but rarely immediately following the brief stimulus. These findings support Stubbs' (1971) hypothesis that the brief stimulus is serving a discriminative stimulus function in second-order schedules. Stubbs (1971) suggested that when

fixed unit schedules (e.g., FI or FR) are used, there is a fixed period of time between the occurrence of the last brief stimulus and food presentation, and thus, the stimuli acquire $S^{\triangle}$ properties. During the first part of the component, food is never presented, so the pigeon paused before responding. Since the relationship between the brief stimuli presentations and the brief stimulus and food was fixed, a pause may occur right after the brief stimulus, since food will never be presented. On the other hand, the relationship between the last brief stimulus presentation and food under the conjunctive schedule is variable, thus a constant rate would be expected. Any fixed-ratio patterning found the present experiment occurred under the paired brief stimulus conditions during the second-order schedule. An interaction between the two components might have resulted in the development of pauses at various times during the conjunctive schedule, and/or the lack of such discriminative control during the second-order schedule, a hypothesis consistent with the present findings. Since the brief stimulus, an amber keylight, was the same for both schedule components, such an interaction was possible.

CHAPTER IV

EXPERIMENT III: THE UNIT AS AN OPERANT

Introduction

Regardless of the role assigned to brief stimuli in various experiments, investigators have found that the unit schedule performance under a second-order schedule may be executed in the same manner as a single "simple" response. Under the second-order schedule FI t(FR n:S) it has been determined that few fixed ratios are emitted at the beginning of the interval, with the number increasing until reinforcer delivery (Bradford & Marr, 1976; Byrd, 1972; Kelleher, 1966A; Shull et al., 1972). Consequently, the overall temporal distribution of responses may be similar when reinforced under a fixed-interval schedule, whether the required response is a single response or a fixed-ratio unit comprised of several such responses.

The previous experiments were designed to establish the role of response-reinforcer temporal contiguity as well as the effect of brief stimuli upon performance under these complex schedules of reinforcement. Another possibility is that the fixed-ratio performance is being emitted as if it were a single response. In other words, the unit of analysis in a second-order schedule may comprise the entire unit schedule performance. Operationally, the unit schedule performance is the operant, since the reinforcer depends not upon a single keypeck but the execution of a number of key pecks. The question which merits study is whether or not the unit schedule performance is functionally the operant. For example, in studies

with the second-order schedule FI t(FR n) Bradford & Marr, 1976; Kelleher, 1966a; Shull, et al., 1972), an indication that the fixed-ratio unit was being executed as a single response was that the ratio had unitary properties. That is, once the ratio had begun, responding was completed without pausing, producing within-unit fixed-ratio patterning. Another indication was that the ratios were distributed over the interval in the same temporal pattern as a single response. The pause followed by increased responding was still evident under the second-order schedule, i.e., few fixed ratios were emitted at the beginning of the interval with the number increasing until reinforcer delivery (Bradford & Marr, 1976; Kelleher, 1966a; Shull et al., 1972).

Goals.

If the analogy between a single keypeck under a fixed-interval and the fixed-ratio unit under a second-order fixed-interval is valid, then it is possible that greater overall response requirements may be maintained under the latter schedule by requiring more than one fixed-ratio unit to be emitted. That is, a conjunctive schedule requirement can be added to the second-order schedule. A conjunctive SO FI 20-min(FR n:S^P) FR n schedule specifies that the performance engendered by a fixed-ratio of size n will terminate in a paired brief stimulus (S^P), and the first fixed-ratio of size n will be reinforced after the interval has elapsed only if N-1 of these ratios has been completed prior to the end of the interval. So, if N = 2, then at least one of the fixed ratios must be executed before the end of the interval in order for the first fixed ratio completed after the end of the interval to be reinforced. Thus, if the analogy between a single response requirement under a fixed interval

and the unit schedule requirement under a second-order fixed-interval schedule is valid, then the number of individual keypecks maintained under the conjunctive second-order schedule in Experiment III should be greater then the number of responses maintained with a second-order schedule FI 20-min(FR n:S). However, from performances engendered by conjunctive schedules in previous experiments (Herrnstein & Morse, 1958; Barrett, 1975), we know there is a limitation on the number of responses which can be required under an interval schedule. If we assume this is the case regardless of the reinforced operant, whether it is a single keypeck or a ratio unit, then as the number of fixed ratios required increases, there should be similar effects on rates and patterns of responding as in an ordinary conjunctive FI t FR n. For instance, Herrnstein and Morse (1958) and Barrett (1975) studied a conjunctive FI t FR n schedule and found that the pattern of responding was altered in a consistent manner, i.e., there was a burst of responding which approximated the size of the ratio requirement initiated after the pause, followed by decreased responding until the next reinforcer delivery. Thus, the overall pattern of the second-order fixed-interval schedule should be altered in a manner similar to the simple fixed-interval when a conjunctive ratio requirement is added.

H_1: Adding a conjunctive ratio requirement to a second-order schedule will affect rates and patterns of responding in a similar manner as a fixed-interval schedule when a conjunctive ratio requirement is added.

Method

Subjects.

The subjects for Experiment III were three White Carneaux pigeons,

maintained at 80% of their free feeding weight. All birds had previous experimental histories, including extensive training under a second-order schedule, FI 20-min(FR n:S).

Apparatus.

The experimental chamber for Experiment III was a Grayson-Stadler single-key unit (Ferster & Skinner, 1957). The response key, 2.0 cm in diameter, could be operated with a minimum force of 0.18 N and could be transilluminated from the rear by either a red or white GE 10C7D 120VAC light. The food magazine aperture was 5.1 cm x 4.4 cm located 13.5 cm below the center key and was illuminated by a white GE 10C7D 120VAC light during the feeder cycle. A white GE 10C7D 120VAC chamber lamp was mounted behind a translucent screen on the key panel and was operative during the feeder cycle.

Procedure.

Responding was initially maintained under an FI 20-min schedule. The schedule was then changed to a second-order schedule, so that each fixed-ratio unit (n) completed produced a paired brief stimulus (S^P), a change in the key light color from red to white for 0.75 seconds. The first fixed-ratio of size n begun and completed after 20 minutes was reinforced with 10 seconds access to mixed grain: SO FI 20-min(FR n:S^P). Overall rates of responding, quarter-life values, and cumulative records served as performance measures. Conditions were in effect until responding had stabilized, judged from the cumulative records. Table I shows the conditions for Experiment III. Once responding had stabilized under the second-order schedule with a unit schedule, FR 30:S^P, a conjunctive ratio requirement was added to the second-order schedule: CONJ FI 20-min

(FR 30:S^P) FR N. The value of N was increased on a logarithmic scale (i.e., 3, 6, .0, 17, 30 etc.) until a disruption in the pattern and a decrease in response rates were seen. The same procedure was followed for a fixed-ratio unit of 100 (FR 100:S^P) with the added conjunctive ratio value of 2 (FR 2).

Results

Figures 18, 19 and 20 show average rates of responding for P70, P287, and P289, respectively, under all conditions in Experiment III. In these figures an open circle represents the mean data from the fixed-interval schedule; the bars indicate $\pm$ one standard of the mean. Open triangles represent the second-order schedule with the unit schedule of FR 30:S^P, and its associated conjunctive schedule requirements. Since the FI 20-minute schedule was always in effect, only the conjunctive ratio requirement and the unit requirement will be referred to subsequently. The unit ratio requirement will always be in parenthesis. For the two moderate-rate birds, P70 and P287 (about 0.6 responses/second under control conditions) changing the FI 20-minute schedule to a second-order schedule FI 20-min (FR n:S^P) had the effect of increasing overall response rates. For both these birds, the conjunctive ratio requirement maintained high rates of responding, until the largest value of this requirement. Note the drop in overall response rates for these birds at (FR30:S^P)FR 6 and then the subsequent increase in rates until the highest value of the conjunctive ratio requirement, (FR30:S^P) FR30, at which time rate again decreased to their lowest value under the conjunctive second-order schedule sequences.

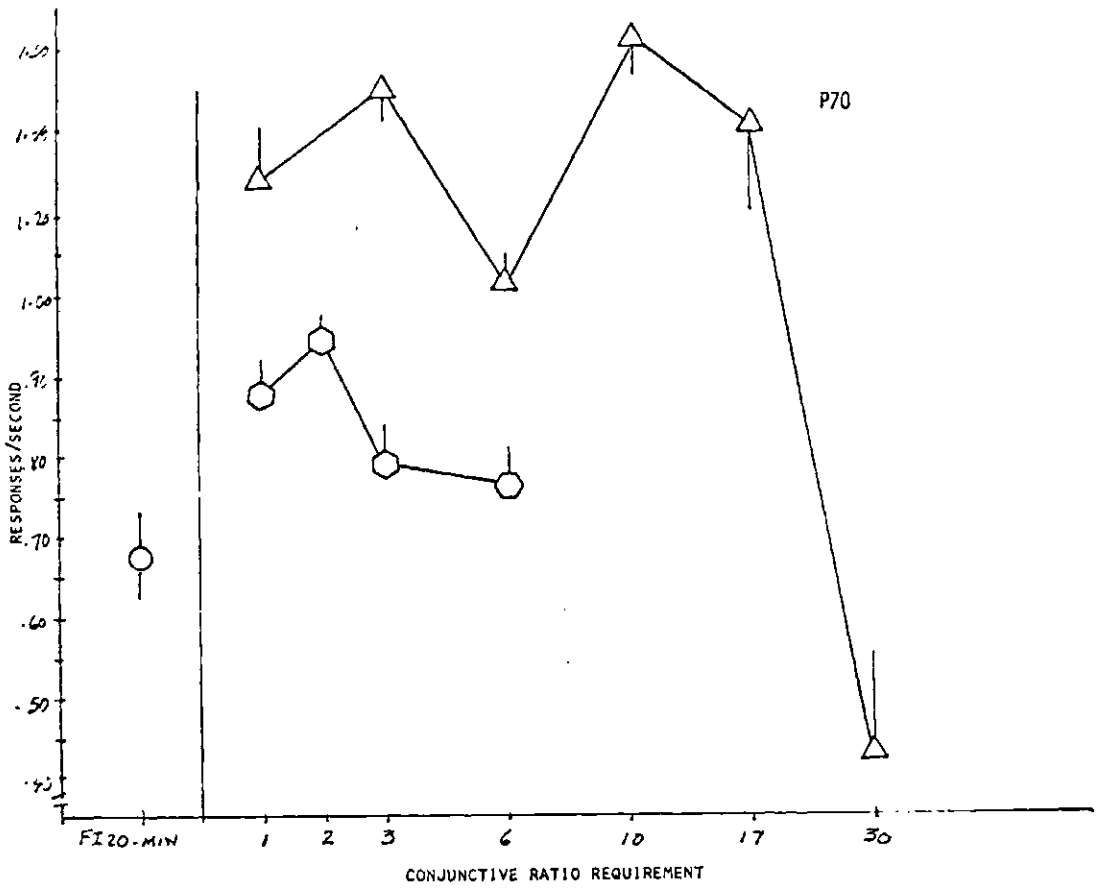

Figure 18. Mean Overall Rates For P70 As A Function Of Schedule Condition. Circles Represent The FI 20-Min Condition; Open Triangles Are The SO FI 20-Min (FR 30:S^P) Condition And Associated Conjunctive Ratio Requirements. Hexagons Indicate The SO FI 20-Min(FR 100:S^P) Condition And Associated Conjunctive Ratio Requirements. Lines Indicate One Standard Error Of The Mean.

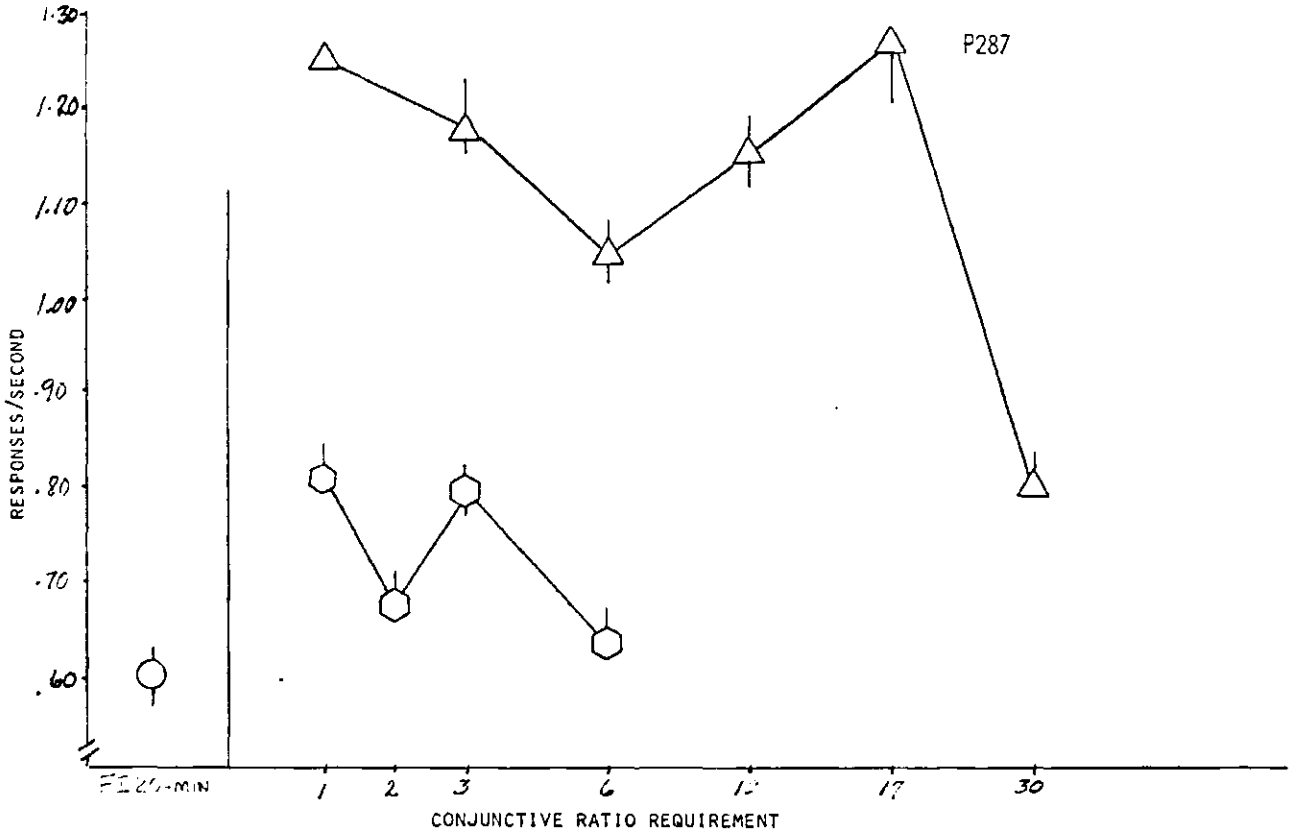

Figure 19. Mean Overall Rates For P287. See Figure 18 For Details.

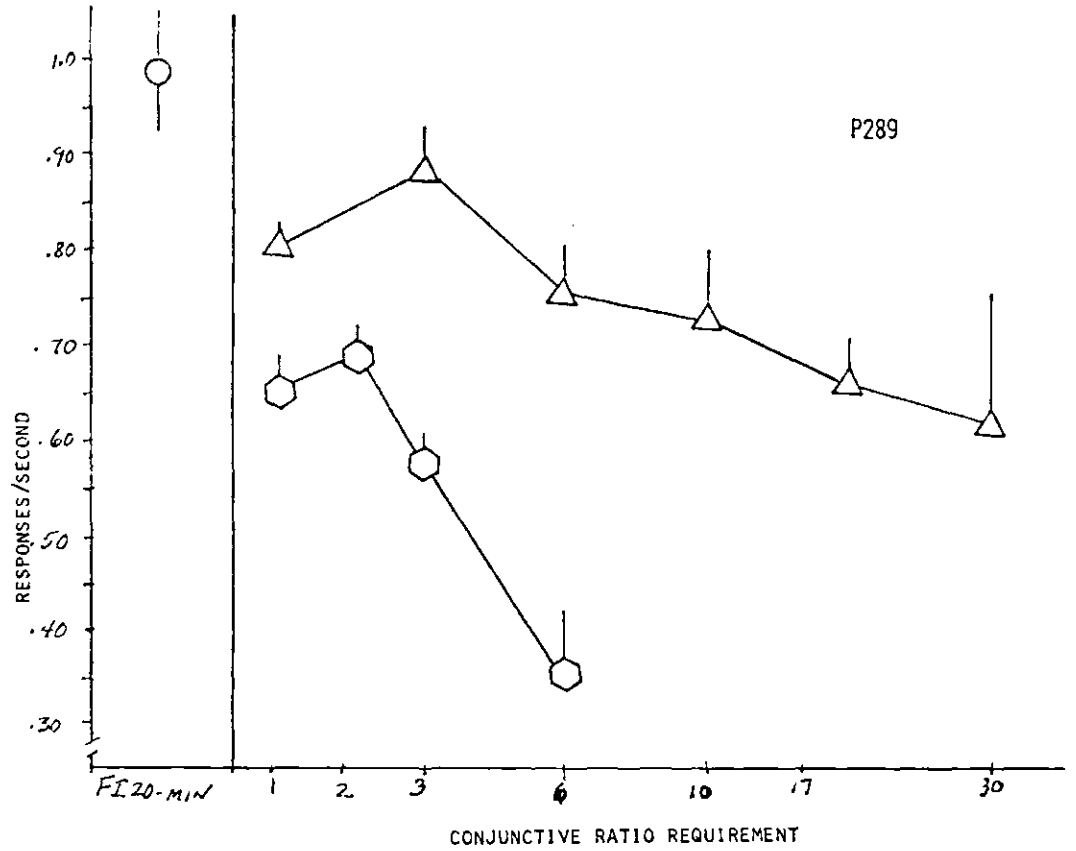

Figure 20. Mean Overall Rates For P289. See Figure 18 For Details.

For P289, a high-rate bird (about 1.0 response/second) changing the schedule to a second-order schedule decreased response rates. Adding a conjunctive schedule requirement had the effect of first slightly increasing then decreasing overall response rates as the conjunctive requirement was further increased.

Overall rates for the second-order schedule with the unit schedule requirement of FR 100:S^P maintained lower rates than the previous unit schedule (FR 30:S^P) for all three birds. However, for P70 and P287, overall rates remained above those of the fixed-interval schedule. Changes in rates when the conjunctive ratio requirement was added under this schedule paralleled that of the first procedure. That is, for P70 and P289, imposing a conjunctive ratio requirement initially increased, then decreased response rates. For P287, the conjunctive ratio requirement first decreased, then increased rates, and at the highest values, again decreased overall response rates.

Figures 21, 22, and 23 show average quarter-life values for P70, P287 and P289, respectively, for all conditions under Experiment III. In general, changing the schedule to a second-order schedule decreased the variability of the quarter-life value for all three birds. Imposing larger and larger conjunctive ratio requirements had the effect of increasing variability of the measures as the ratio requirement increased. In general, for all three birds, an increasing conjunctive ratio requirement first increased, then decreased quarter-life values. At the largest values of a conjunctive ratio requirement under each procedure (unit schedule FR 30 or unit schedule FR 100), quarter-life values greatly increased.

Figures 24, 25, and 26 (P70, P287, and P289, respectively) indicate

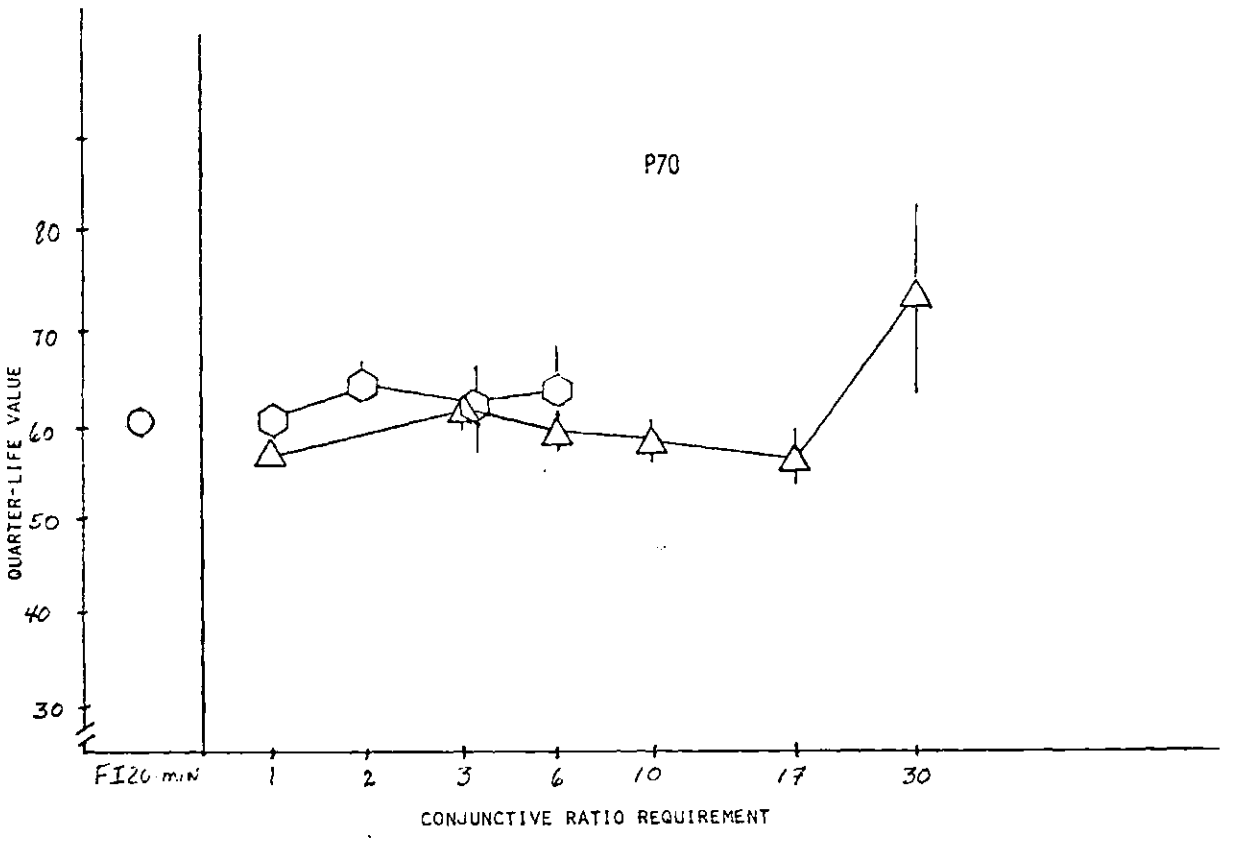

Figure 21. Mean Quarter-Life Values For P70 As A Function Of Schedule Condition. Circles Represent The FI 20-Min Condition; Open Triangles Are The SO FI 20-Min (FR 30:S^P) Condition And Associated Conjunctive Ratio Requirements. Hexagons Indicate the SO FI 20-Min(FR 100:S^P) Condition And Associated Conjunctive Ratio Requirements. Lines Indicate One Standard Error Of The Mean.

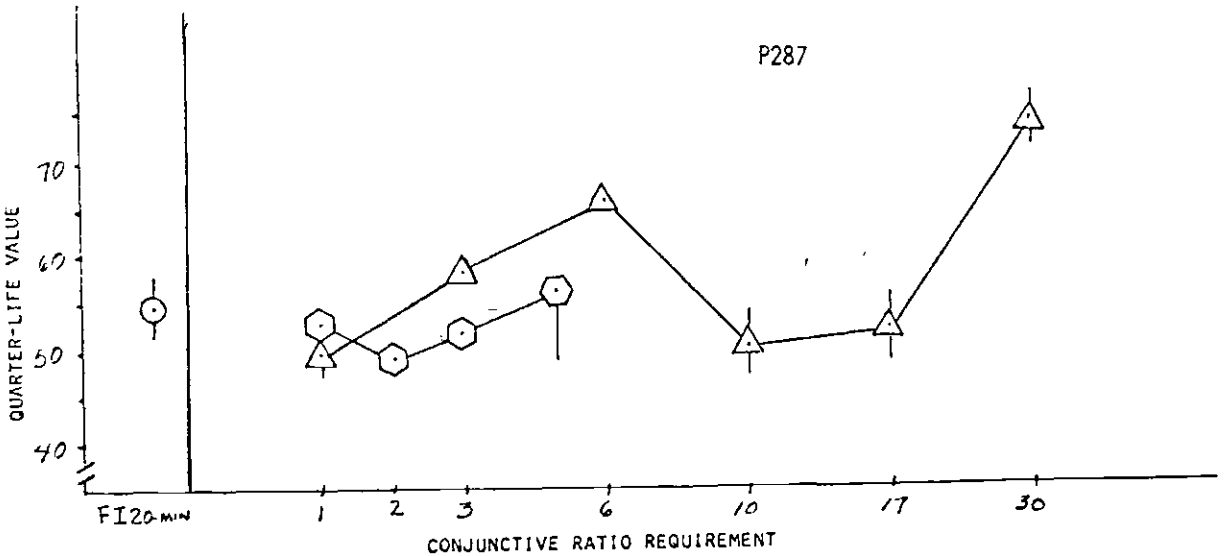

Figure 22. Mean Quarter-Life Values For P287. See Figure 21 For Details.

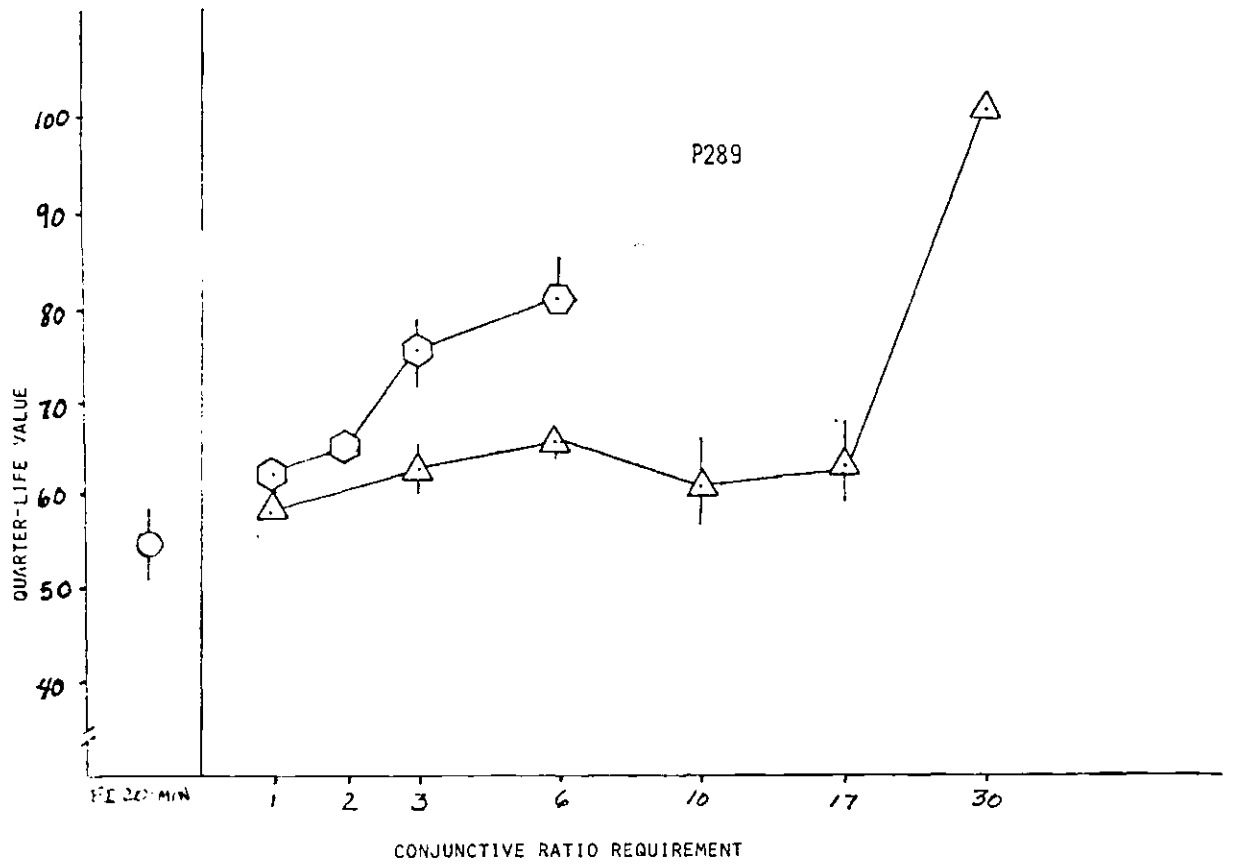

Figure 23. Mean Quarter-Life Values For P289. See Figure 21 For Details.

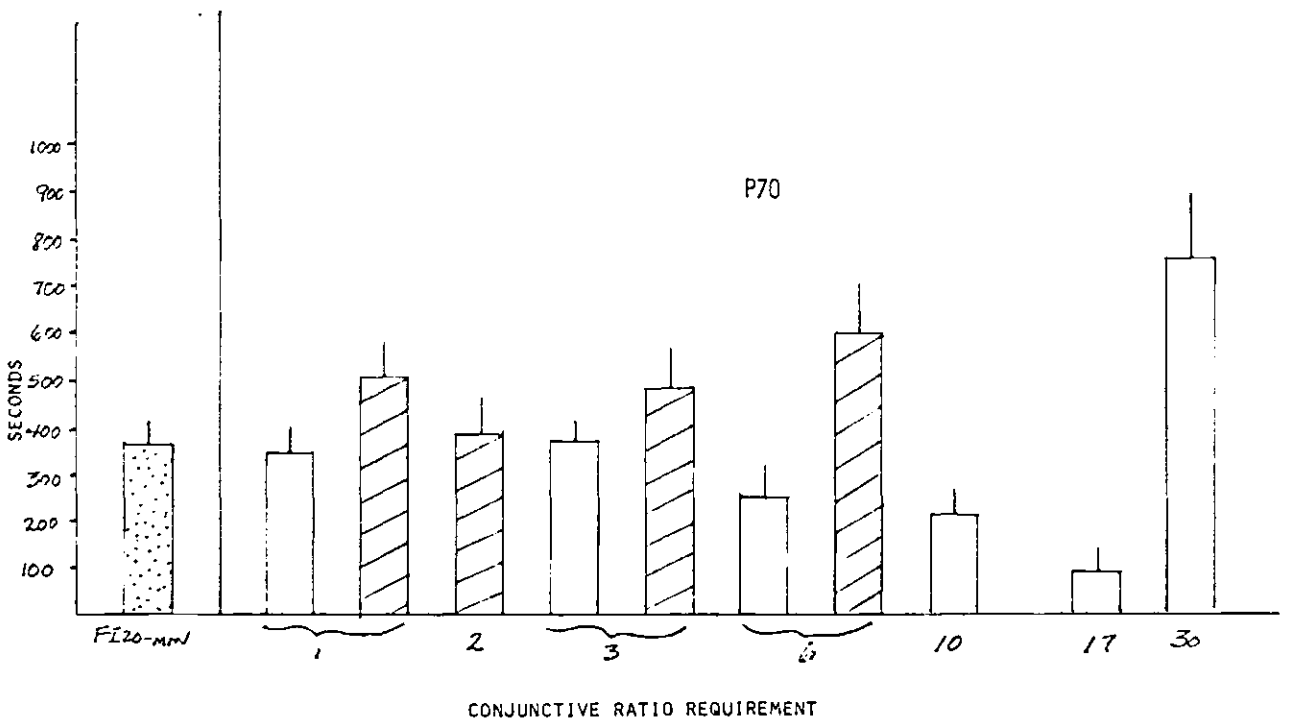

Figure 24. Mean Pause Time Per Reinforcer For P70. The Stippled Bar Is The FI 20-Min Condition; The White Bars Are The SO FI 20-Min(FR 30:S^P) Condition And Associated Conjunctive Ratio Requirements. Single Hatched Bars Are The SO FI 20-Min(FR 100:S^P) Condition And Associated Conjunctive Ratio Requirements. Lines Indicate One Standard Error Of The Mean.

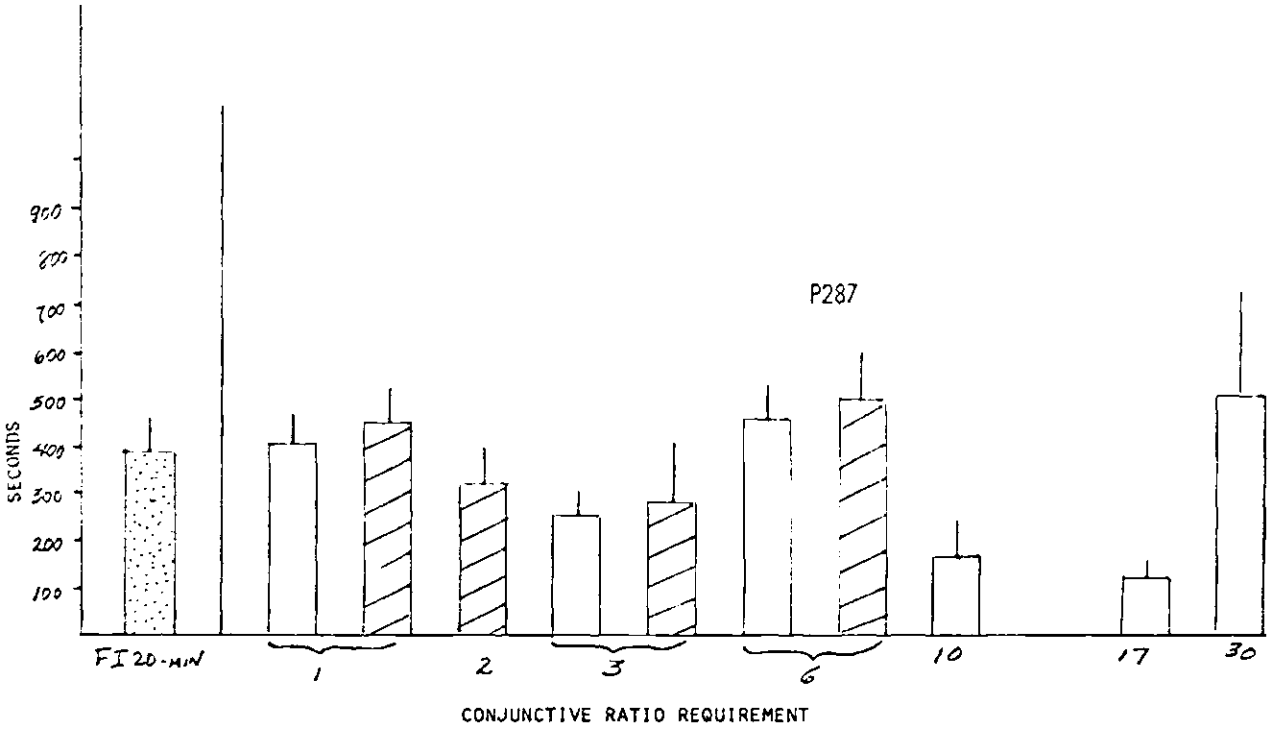

Figure 25. Mean Pause Time Per Reinforcer For P287. See Figure 24 For Details.

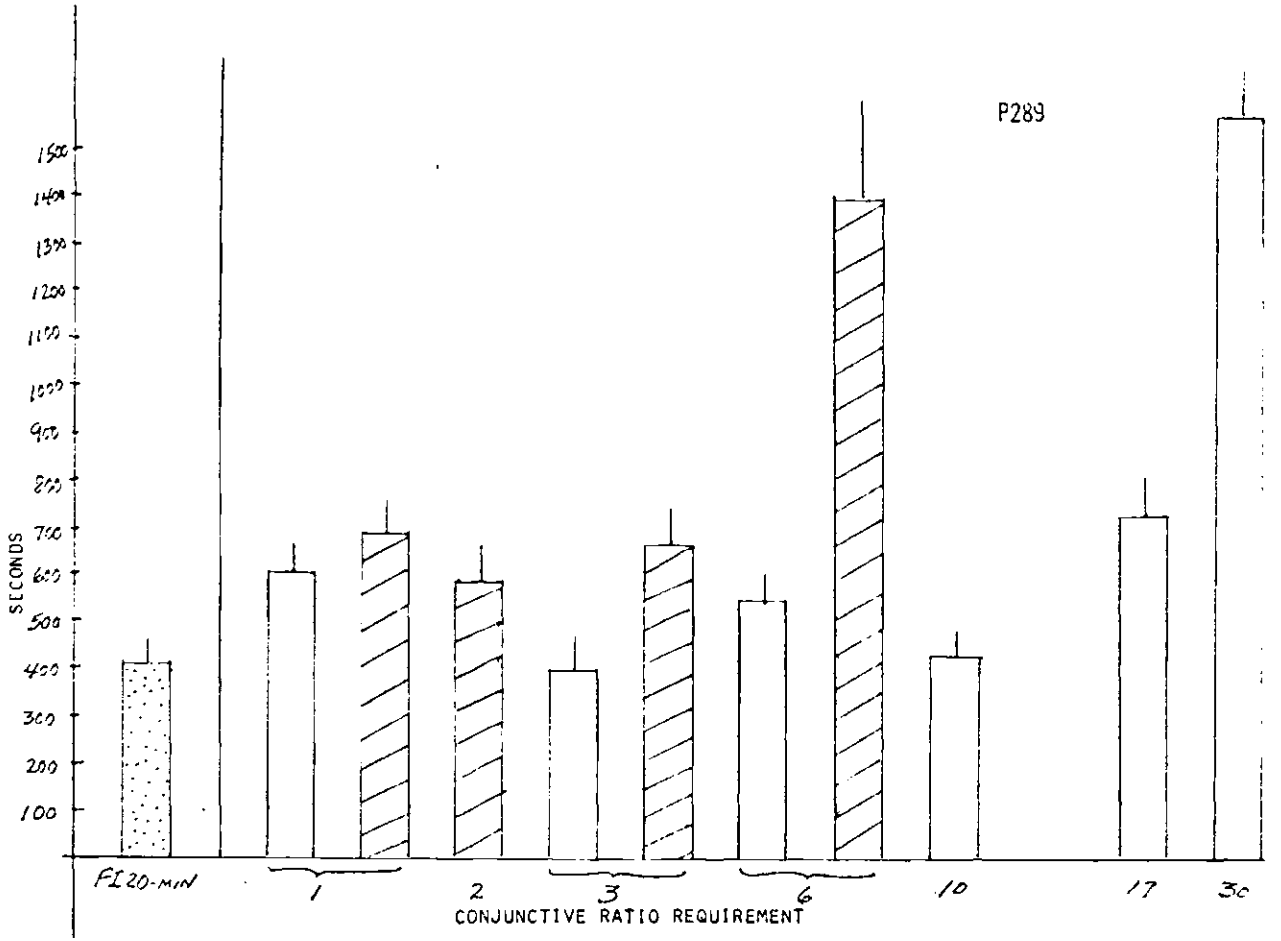

Figure 26. Mean Pause Time Per Reinforcer For P289. See Figure 24 For Details.

the average pause time per reinforcer. The stippled bars indicate the fixed-interval schedule; the white bars represent the second-order schedule with the unit schedule, FR30; and the single hatched bars represent the conditions with the unit schedule requirement, FR 100, the lines through the bars indicate one standard error of the mean. All measures were derived from the cumulative records from the last three days of a condition. Under the FI 20-minute schedule, all three birds were pausing for about one-third of the 20-minute interval (about 400 seconds). Under the second-order schedule, the pause increased slightly for all birds, except P70 at the FI 20-min(FR 30:S^P) condition. Thereafter, the conjunctive ratio requirement had the effect of generally decreasing the average pause time until the larger values of the conjunctive ratio requirement. The range of values for P70 under the (FR 30:S^P) FR 6 condition was large, there were instances when P70 paused for very long intervals, explaining the drop in overall rates under that condition seen in Figure 18. Also note the average pause time increased for P287 under the same condition (Figure 25), thereby explaining the decrease in rates for this bird under that condition, seen in Figure 19. At the largest value of the conjunctive ratio requirement, the birds paused for about 37 minutes (P70, P289) or 80 minutes (P287) during a single interval.

The average interreinforcer time, i.e., the interval between food deliveries, can be seen in Figures 27 (P70), Figure 28 (P287) and Figure 29 (P289). Again, changing the fixed-interval schedule to a second-order schedule had the effect of increasing the interreinforcer time in proportion to the unit schedule requirement. Thereafter, adding a conjunctive ratio requirement served to further increase the average interreinforcer

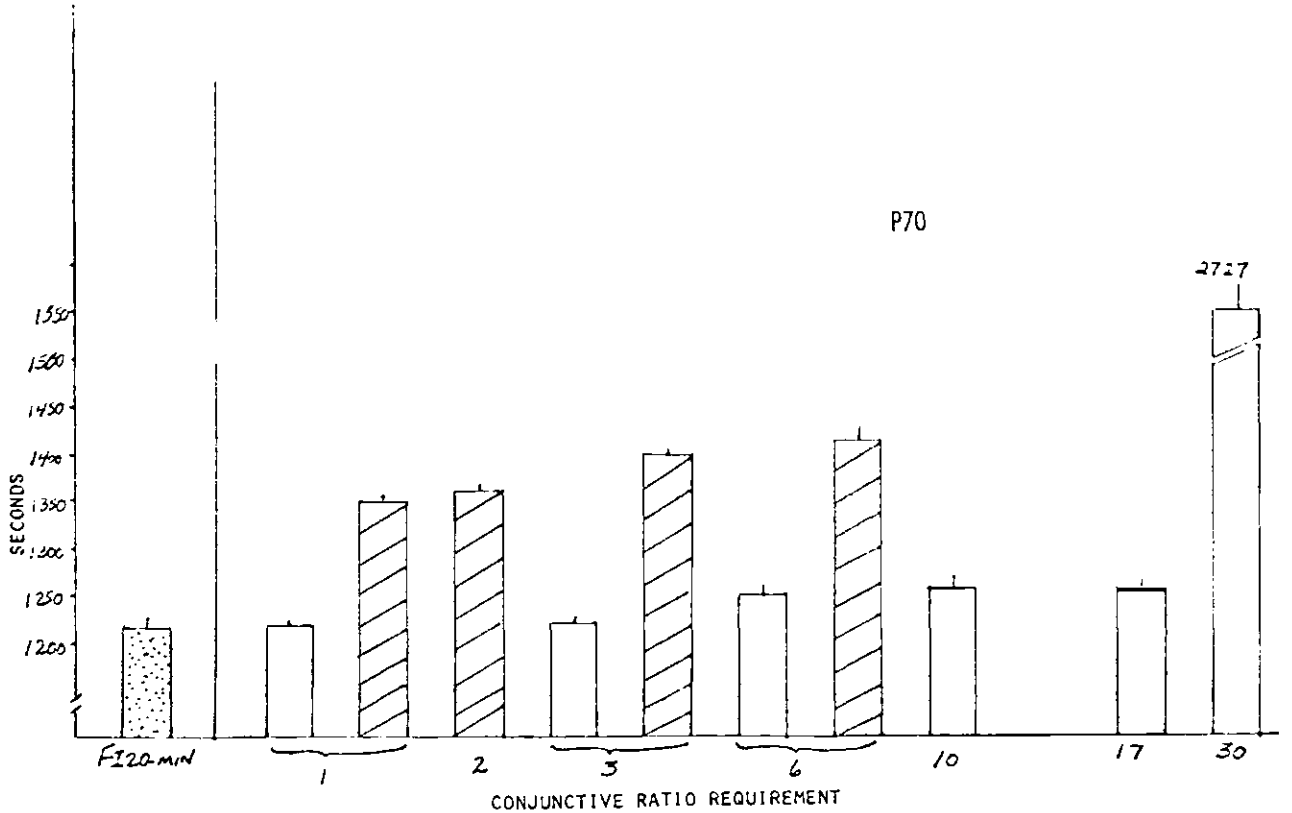

Figure 27. Mean Interreinforcer Time For P70. The Stippled Bar Is The FI 20-Min Condition; The White Bqrs Are The SO FI 20-Min(FR 30:S^P) Condition And Associated Conjunctive Ratio Requirements. Single-Hatched Bars Are The SO FI 20-Min(FR 100:S^P) Condition And Associated Conjunctive Ratio Requirements. Lines Indicate One Standard Error Of The Mean.

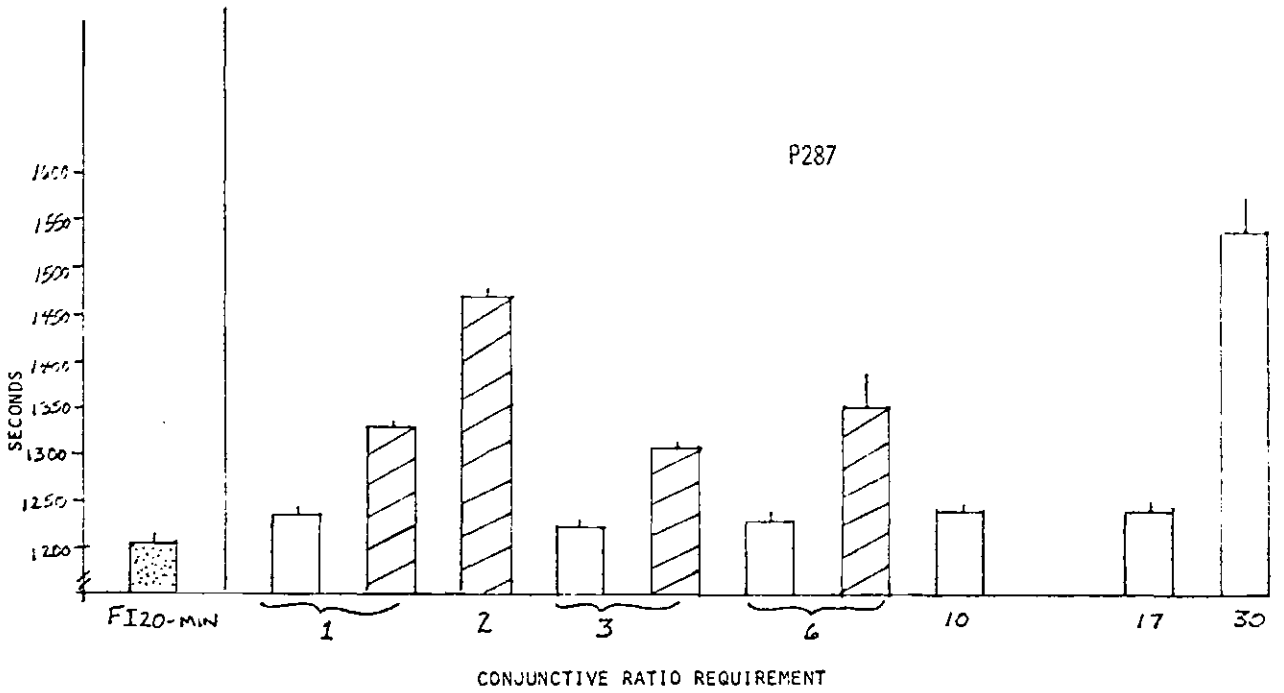

Figure 28. Mean Interreinforcer Time For P287. See Figure 27 For Details.

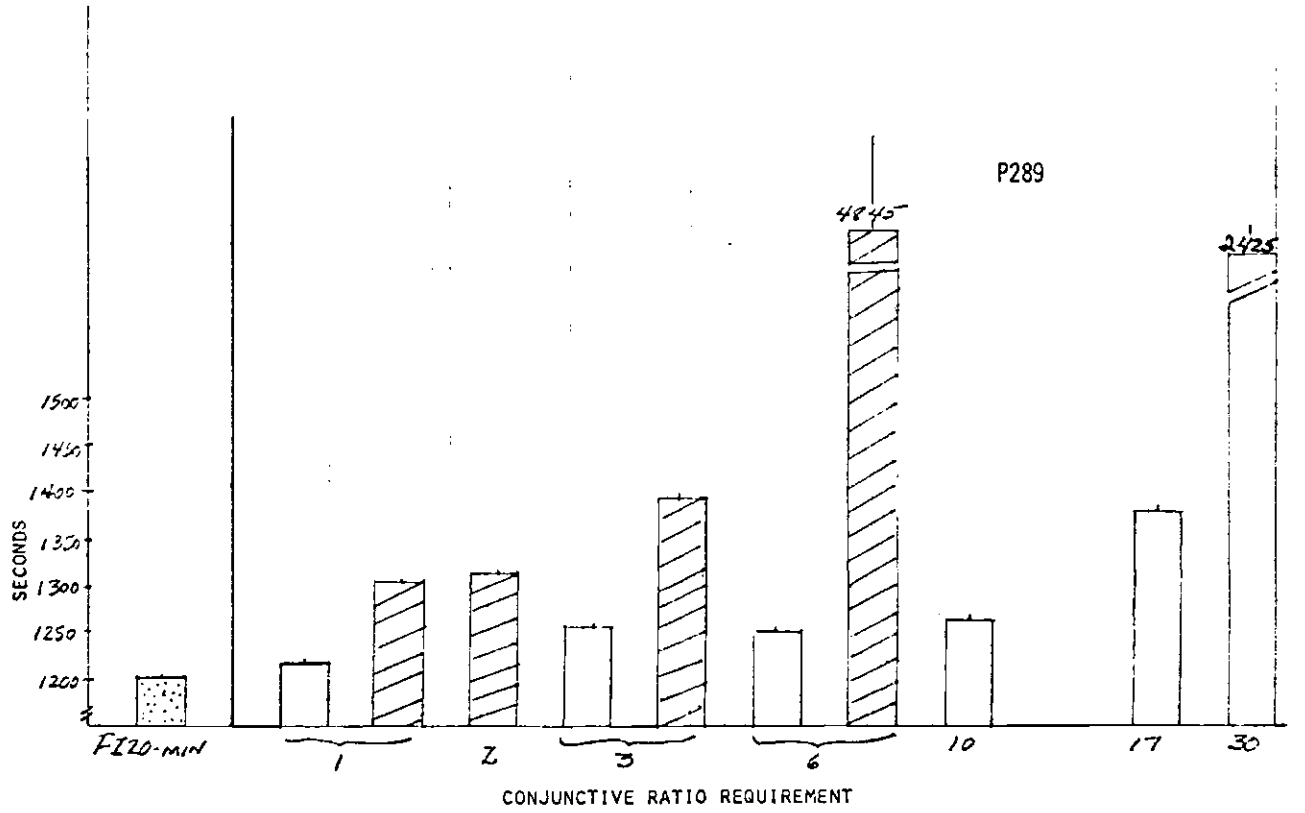

Figure 29. Mean Interreinforcer Time For P289. See Figure 27 For Details.

interval as the ratio was increased under the conjunctive requirement. There was a considerable increase under the largest values of the conjunctive response requirement. For example, under the schedule (FR 30:S^P) FR 30 on the average, P70 and P289 took about 45 minutes to complete the interval requirements. The entire session for these two birds would take from about 6 to 8 hours, compared to about 3.5 hours under the second-order schedule without a conjunctive ratio requirement.

Figure 30 presents cumulative records for P287 chosen from the last three days of the FR 30:S^P unit conditions. Panel 1 is from the simple fixed-interval schedule; 2 represents the FI 20-min(FR 30:S^P) condition; 3 is from the (FR 30:S^P) FR 3 condition, panel 4, (FR 30:S^P) FR 6; panel 5 is from the (FR 30:S^P) FR 10 condition; panel 6 represents the (FR 30:S^P)FR17 condition, and panel 7 is taken from the (FR 30:S^P) FR 30 condition. In comparing the fixed-interval schedule with the second-order schedule (panel 1 and panel 2), the pause increased shomwhat in the latter, but the transition to a higher rate is also evident. Once the conjunctive ratio requirement was added, the initial pause tended to decrease (e.g., at a,a', and a''), but there was often a second pause following the initial burst of responding, e.g., at b, b', and b''. However, there were also instances of intervals which closely resembled the standard second-order schedule, e.g., c. Finally, at larger values of the conjunctive ratio requirement, the birds would often pause the entire length of the interval before responding, e.g., d, and would complete the entire conjunctive ratio requirement after the interval elapsed. These instances occurred at lower conjunctive ratio ralues for P70 and P289. All three of these patterns of responding: the pause-run-pause-run pattern, the standard

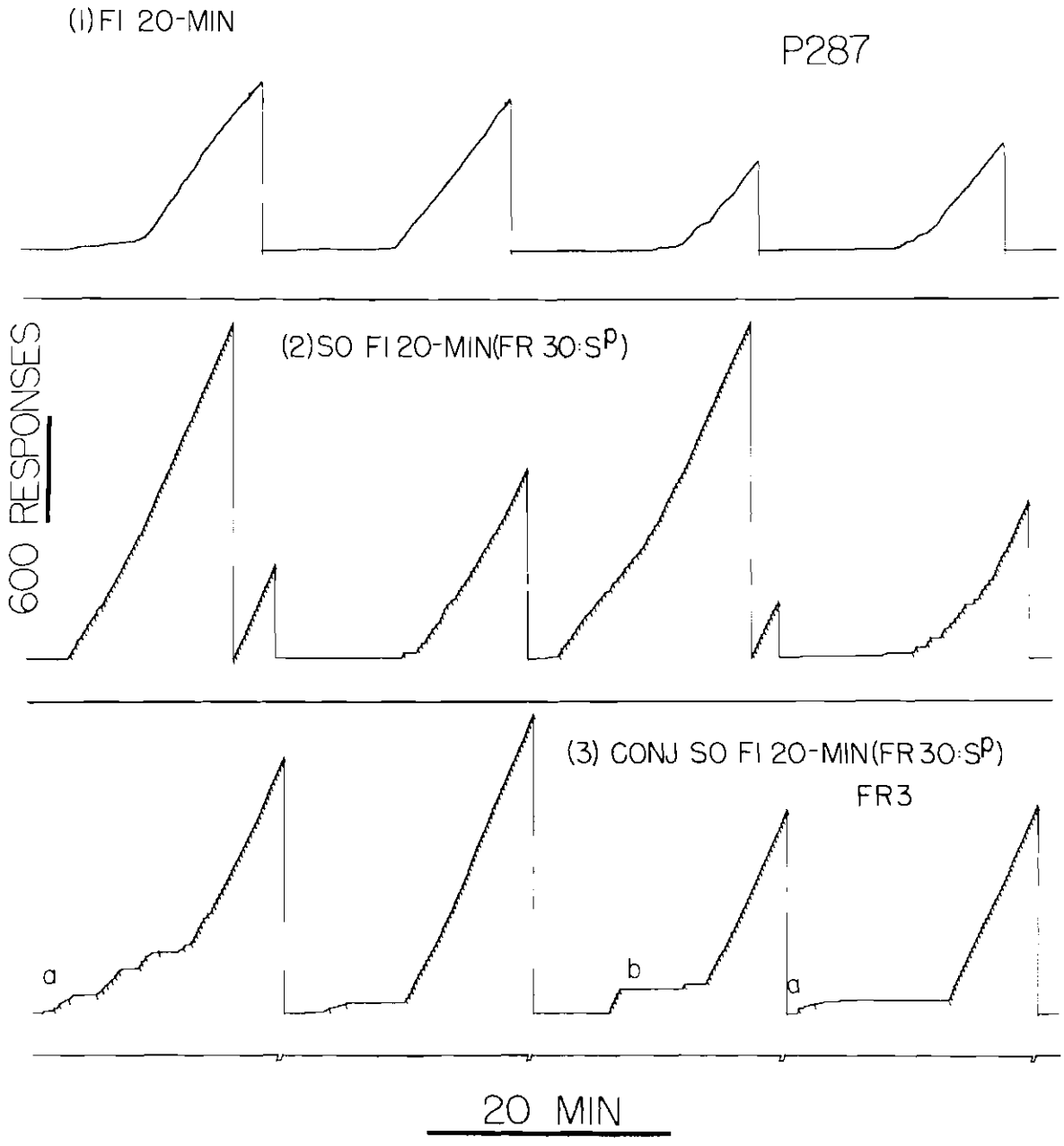

Figure 30. Cumulative Records For P287 From Each Condition Of Procedure 1, Experiment III: (1) FI 20-Min, (2) SO FI 20-min(FR 30:S^P), (3) CONJ SO FI 20-Min(FR 30:S^P)FR 3 (4) CONJ SO FI 20-Min(FR 30:S^P)FR 6, (5) CONJ SO FI 20-Min (FR 30:S^P) FR 10, (6) CONJ SO FI 20-Min(FR 30:S^P)FR 17, (7) CONJ SO FI 20-Min(FR 30:S^P) FR 30.

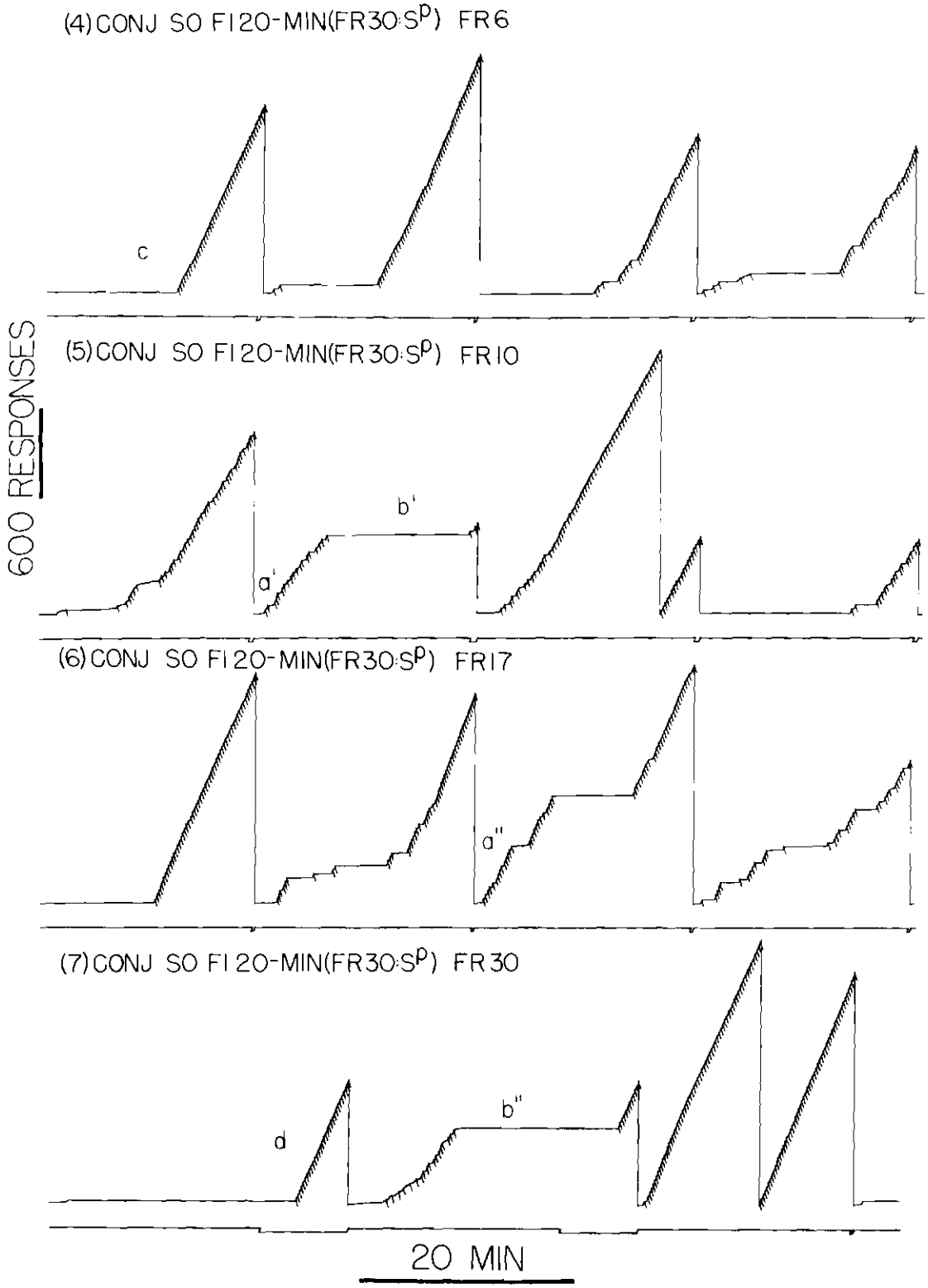

Figure 30. Continued.

interval pattern, and the pause through-out the interval added to the variability found in the average measures taken, such as pause time, the interreinforcer time, and the quarter-life values. Note also that when responding was again initiated after the second pause in an interval, it was usually at a very high rate, perhaps because of the rate-enhancing effects of a stimulus paired with food, the effect of food itself, or the reinforcement of short IRTs under the unit schedule.

Figure 31 presents cumulative records for P70 during the second procedure (unit schedule, FR 100) under Experiment III. The top record is from the standard second-order schedule: So FI 20-min(FR 100S^P), the second row presents adding a conjunctive FR 2 requirement, the third, conjunctive FR 3, and fourth, conjunctive FR 6. In the (FR 100 S^P) FR 2 conditions. By the (FR 100 S^P) FR 6 condition, this bird was pausing the entire length of the interval during several segments (e.g., at b).

Fixed-interval schedules demonstrate regenerative properties. That is, when the organism pauses during much of the interval so that the reinforcement probability per response is high, this can serve to strengthen responding so that in succeeding intervals more responses may be emitted. However, the result of this increased responding means now that the reinforcement probability per response is low, weakening responding, and so on. Figure 32 presents cumulative records from all three birds demonstrating this phenomenon under various conditions. The top record is from the fixed-interval schedule (P287), followed by a conjunctive second-order schedule (FR 30:S^P) Fr 10 (P70), then (FR 30:S^P) FR 10 (P289). Finally, the bottom record is from the (FR 100:S^P) FR 2 condition (P287). Note at a in each record, a single response requirement (whether a single

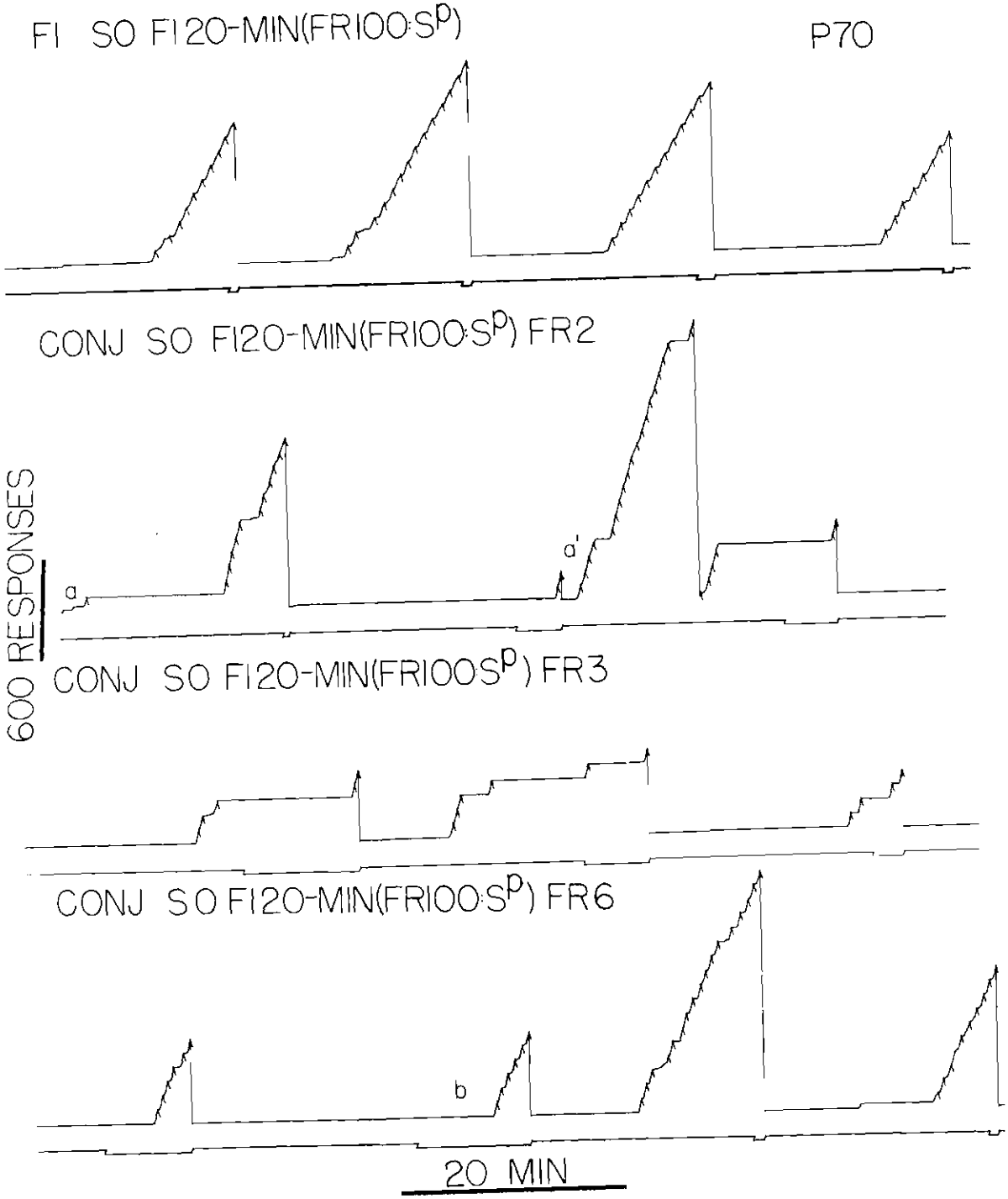

Figure 31. Cumulative Records For P70 From Each Condition Of Procedure 2, Experiment III: (1) SO FI 20-Min(FR 100:S^P), (2) CONJ SO FI 20-Min(FR 100:S^P) FR 2, (3) CONJ SO FI 20-Min(FR 100:S^P)FR 3, (4) CONJ SO FI 20-Min(FR 100:S^P)FR 6.

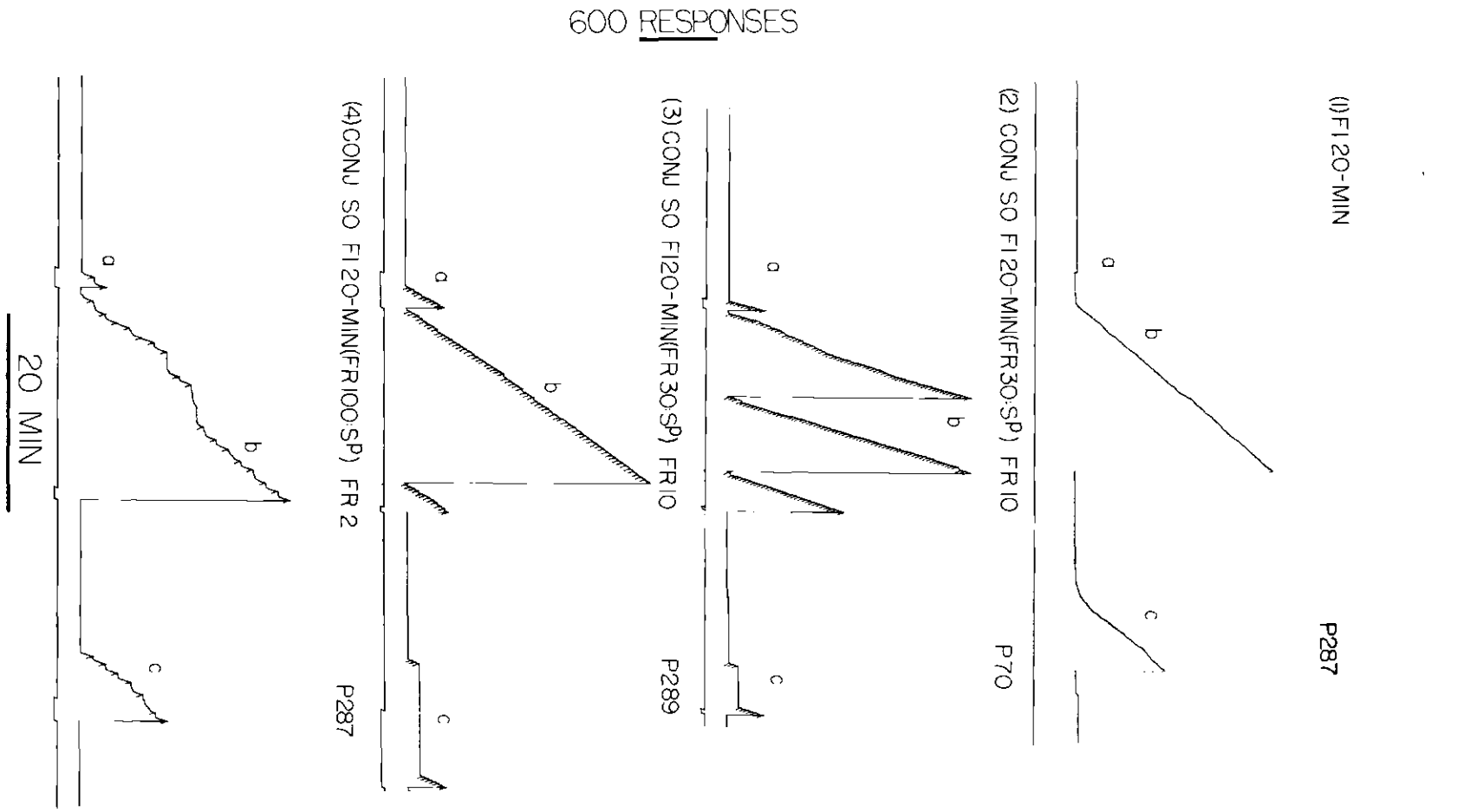

Figure 32. Selected Cumulative Records Showing The Regenerative Property of FI Schedules. (1) P287, FI 20-min, (2) P70, CONJ SO FI 20-Min(FR 30:S^P)FR 10, (3) P289, CONJ SO FI 20-Min(FR 30:S^P)FR 10, (4)P287, CONJ SO FI 20-Min(FR100:S^P)FR2. See Text For Details.

response or a complex unit response or a complex unit response) was emitted. The following interval (b) contains many responses, followed by an interval (c) containing a moderate number of responses. Note also the interaction of variables producing variations in patterns under the more complex schedules. This regenerative nature of fixed-interval schedules helps to explain the increase of responding for both P70 and P287 after the (FR 30:S^P) FR 6 condition. At these levels of the conjunctive ratio requirement, the requirement was sometimes emitted as a single unit in close contiguity with the reinforcer, thus serving to further strengthen responding in subsequent intervals. This was seen less often with P289. Once the conjunctive ratio requirement was increased to a certain point, however, so that many such intervals occurred, response rate were then decreased.

Discussion

The results from Experiment III were consistent with those from Experiment I and II. The interreinforcer time increased only slightly compared to the increased initial pause time with increasing values of the conjunctive ratio requirement. In addition, conjunctive schedule patterns were like those seen under the standard conjunctive schedule in Experiments I and II as well as previous experiments (Barrett, 1975; 1976). Thus this complex schedule maintained responding in the same manner as simpler schedules. This could only be the case if the fixed-ratio unit were functionally the operant, since it changed in the same manner as a single response in simple schedules. Other aspects of the present experiments also support the fixed-ratio unit as the functional operant. In

Figure 32, there were demonstrations of the regenerative properties of fixed-interval schedules, not only of a single keypeck, but of a more complex unit as well. In addition, during Experiment II, when the birds paused the entire length of the interval under the second-order schedule, then emitted only the unit response (high reinforcement probability), responding in the following conjunctive schedule was often greatly enhanced. (Also an indication of an interaction between the two components of the multiple schedule.) A careful examination of the cumulative records revealed no such enhancement of responding in the subsequent second-order schedule when the conjunctive schedule requirement was met after the interval had elapsed.

CHAPTER V

GENERAL DISCUSSION AND CONCLUSIONS

The preceding experiments were designed to investigate the variables that are assumed to control performance under second-order and conjunctive schedules of reinforcement. In Experiment I, the effects on performance of arranging responses and reinforcement in different temporal relationships were compared. Consequent stimuli which may have altered responding by either increasing or decreasing rates and/or changing the pattern of responding were introduced in Experiment II. The role of a consequent stimulus and its association with food was also examined (S^{np} vs. S^{p}). Finally, the cohesive properties of unit performance under the second-order schedule were tested in Experiments II and III. The results of Experiment III determined if adding additional unit schedule requirements to a second-order schedule altered performance in the same manner as when additional single responses are required under a fixed-interval schedule of reinforcement.

To summarize the goals of these experiments:

1. To investigate the effects upon performance of different temporal relationships between responses and reinforcers.
2. To investigate the effects of brief stimulus presentations upon complex schedule performance, and determine the extent to which these depend upon the association of the stimulus with food.
3. To test the extent to which unit schedule performance is executed

as a single response.

4. To attempt to extend the general principles underlying behavior, such as patterns and rates of responding, under simple schedules of reinforcement to more complex schedules.

In Experiment I, responding was maintained under both the conjunctive and second-order schedules throughout the ranges of values examined. At the largest value of the ratio (FR 300), responding became strained, i.e., long pauses occurred, so that the ratio requirement was completed after the interval had elapsed under both schedules. However, the response measures clearly indicate a difference between the two schedules, especially in the terminal segments when responses were close to the reinforcer. But does Baum's contention of a more molar view, a "correlational" law of effect add any more to our understanding of schedule-controlled behavior? Is Baum really saying any more than when a response is reinforced, preceding responses are also strengthened, (Catania, 1971). Rather, it is suggested that the behavior occurring during the early segments of the conjunctive schedule interval (resulting in a reduced pause time) was sensitive to the presentation of a temporally distant event, i.e., the reinforcer terminating the interval (Barrett, 1976). Formulation of a new "correlational" law of effect is not necessary to explain the present findings.

There was evidence presented in Experiment II that the brief stimulus may be serving a discriminative function in second-order schedules, resulting in within-unit patterning. The presence of patterning was seen only in the second-order schedule components where there was a fixed relationship between brief stimulus presentations and food, but was absent in

the conjunctive schedule where that same relationship was variable. In addition, the patterning that was present in the second-order schedule was most often seen close to the end of the interval. This again supports the discriminative stimulus hypothesis, since the closer to the reinforcer, the more control the brief stimulus would exert over responding. Little evidence of patterning was seen in the early segments of this long (20 min) interval.

Finally, from all three experiments, the regenerative property of the fixed-interval schedule was seen, whether a single response or a complex unit was in question. In addition, Experiment III provided evidence that the unit schedule performance was acting as a single response, since changes in response measures paralleled those seen in fixed-interval schedules when a conjunctive ratio requirement was added. However, that is not to say that the second-order schedule was without influence, providing variations in the in the pattern of responding. For instance, the negative acceleration in the terminal segments often seen under the conjunctive schedules in Experiments I and II was not observed in the conjunctive second-order schedule. Thus, it appears that the reinforcement of short IRTs associated with ratio unit requirements maintained increasing rates during these terminal segments. Thus, both schedule requirements, the conjunctive schedule and the second-order schedule, exerted their influence over the pattern and rates of responding.

In Experiments I and II, adding a ratio requirement to a fixed-interval schedule had the effect of increasing overall response rates under both the conjunctive and the second-order schedule components. At the largest value of the ratio requirement, rates decreased in the brief sti-

mulus procedures. A conjunctive second-order schedule was investigated in Experiment III. When a conjunctive ratio requirement was added to the second-order schedule, overall rates increased and then decreased at the highest values of the ratios. In experiments I and II, although the terminal rates in the second-order schedule component were higher, the interaction with the increased pause time and the interreinforcer time, coupled as interaction would be to use different stimuli for the brief stimulus in each component. However, until the variables controlling the behavior under each of these schedules, the conjunctive and the second-order schedules, are more clearly understood, it would be advantageous to study them in isolation. Once the controlling variables are determined, then it would be informative to study these schedules arranged in a multiple schedule, and directly manipulate possible interactions such as contrast and inductive effects (Reynolds, 1961), between the two components. If the increased interreinforcer time is playing an important role under the second-order schedule, the length of the interval should be adjusted to compensate for increased sizes of unit schedule requirements.

Finally, additional empirical evidence is needed to establish the role of the brief stimulus under complex schedules of reinforcement. The present experiment (II) supports the discriminative stimulus hypothesis. However, more complex schedules should be studied in which the relationship between brief stimuli presentations and the brief stimulus presentation and food is not fixed (i.e., conjunctive, concurrent, and conjoint schedules).

It appears that although second-order schedules were, in part, designed to study the conditioned reinforcing effects with the fact that

responding began sooner (shorter pause time) in the conjunctive schedule, kept the overall rates in both components about the same. The conjunctive second-order schedule, on the other hand, combined both these rate-enhancing effects for P70 and P287. Pause times were not significantly increased until the largest value of the conjunctive ratio requirement. This fact, combined with a positively increasing rate of responding during the terminal segments, as well as the regenerative property of the fixed-interval, resulted in greater absolute rate changes under this complex schedule.

CHAPTER VI

IMPLICATIONS FOR FUTURE RESEARCH

The present experiments have shown that each of the variables which control behavior under fixed-interval schedules also exert their influence under more complex schedules. The imposed response requirements exert their influence, as well. These variables interact with the ongoing behavior in a complex manner. The interactions lead to greater variability in performance measures which are ordinarily stable in fixed-interval schedules (e.q., quarter-life values, pause time, etc.). However, the fact that these complex schedules yield more complicated interactions with the behavior is encouraging since human behavior then is maintained by reinforcing stimuli in the normal environment is also characterized by variability. Following are suggestions to reduce this variability so that the appropriate variables under these complex schedules can be isolated.

Experiments I and II seemed to have been further complicated by presenting the two schedules as components in a multiple schedule. Not only did the behavior within components interact with the dependencies scheduled for that component, but there may have been an interaction between components, as well. One way to possibly eliminate such an interaction would be to use different stimuli for the brief stimulus in each component. However, until the variables controlling the behavior under each of these schedules, the conjunctive and the second-order schedules, are more clearly understood, it would be advantageous to study them in isola-

tion. Once the controlling variables are determined, then it would be informative to study these schedules arranged in a multiple schedule, and directly manipulate possible interactions such as contrast and inductive effects (Reynolds, 1961), between the two components. If the increased interreinforcer time is playing an importnat role under the second-order schedule, the length of the interval should be adjusted to compensate for increased parameter values of the unit schedule.

Finally, additional empirical evidence is needed to establish the role of the brief stimulus under complex schedules of reinforcement. Experiment II supported the discriminative stimulus hypothesis. However, other schedules should be studied in which the relationship between brief stimuli presentations and the brief stimulus presentation and food is not fixed (i.e., conjunctive, concurrent, and conjoint schedules).

It appears that although second-order schedules were, in part, designed to study the conditioned reinforcing effects of brief stimuli, fixed units provide an inherent fixed realtionship, and therefore negates the possible usefulness of this schedule to that end. However, the second-order schedule has proven to be a useful tool in investigating the question of the funcational operant in schedule controlled behavior. Additional experiments merit investigation of combining other schedule requirements with that of the second-order schedules, as in Experiment III, to explore more fully the complex units of behavior.

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